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EXTRA CLASS

RADIO AMATEUR LICENSE GUIDE

FCC QUESTIONS & EASY-TO-UNDERSTAND ANSWERS
FCC-TYPE MULTIPLE CHOICE PRACTICE EXAM
QUESTIONS GROUPED BY SUBJECT

75¢

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"AMECO"

EXTRA CLASS RADIO AMATEUR LICENSE GUIDE

by

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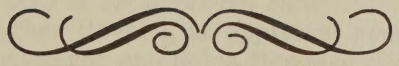

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PREFACE

The AMECO EXTRA CLASS RADIO AMATEUR LICENSE GUIDE is part of a series of guides published by the Ameco Publishing Corp. for the purpose of preparing students for the Federal Communication Commission's amateur radio operator's examinations.

As is the case with the other AMECO guides, this guide includes a sample FCC-type examination. This sample examination provides an added means of preparation for the actual FCC examination, and may serve as an accurate gauge of preparedness. The correct answers to the questions are in the back of the book. The questions duplicate the format of the FCC exam; most of them are of the multiple-choice type and cover the entire range of material that is covered by the FCC on their examination.

In addition to the other elements, the satisfactory completion of the Extra Class examination is necessary for the Extra Class Amateur License. The following are the requirements for the various classes of amateur radio operator's licenses issued by the Federal Communication Commission.

Amateur Extra Class - Elements 1(C), 3, 4(A) and 4(B).
Advanced Class - Elements 1(B), 3 and 4(A).
General and Conditional Classes - Elements 1(B) and 3.
Technician Class - Elements 1(A) and 3.
Novice Class - Elements 1(A) and 2.

Element 1(A) is a 5 w.p.m. code test; Element 1(B) is a 13 w.p.m. code test and Element 1(C) is a 20 w.p.m. code test. Element 2 is a written test on basic laws; Element 3 is a written test on general amateur practice and regulations; Element 4(A) is on intermediate radio theory and Element 4(B) is on advanced radio theory.

In going for a higher license, an applicant need not repeat elements which he has already passed and holds licenses requiring them.

The FCC examination for the Extra Class (Element 4(B)) consists of 50 multiple-choice questions, similar to the examination on Page 39. Two percent (2%) credit is allowed for each question answered correctly. Seventy-four percent (74%) is the passing mark for the examination element.

Although this guide covers only Element 4(B) of the amateur radio operator's examinations, the Ameco Publishing Corp. has published other guides covering the other elements. License guides covering the requirements for the commercial radio operator examinations have also been published. These are all described on the back cover.

It is the contention of the author that the student who thoroughly covers the material in this guide will be prepared to pass the FCC amateur radio operator's examination.

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EXTRA CLASS
QUESTIONS AND ANSWERS

DC AND AC THEORY

Q. 1. WHAT ARE INDUCTIVE AND CAPACITIVE REACTANCE? HOW ARE THEIR PHASE ANGLES RELATED? HOW DOES THEIR REACTANCE AFFECT ACTUAL POWER DISSIPATION IN A CIRCUIT?

A. Inductive reactance is the opposition that an inductance offers to AC. It is given in ohms and is found by the formula:

$$X_L = 2\pi fL$$

where X_L is the inductive reactance, f is frequency in cycles and L is inductance in henries.

Capacitive reactance is the opposition that a capacitor offers to AC. Its formula is:

$$X_C = \frac{1}{2\pi fc}$$

where X_C is the capacitive reactance in ohms, f is frequency in cycles and C is the capacity in farads.

In an inductance, the current lags behind the voltage by 90° and in a capacitance, the current leads the voltage by 90°. If we plot this vectorially, we see that the inductive reactance is 180° out of phase (or opposite to) with the capacitive reactance.

Pure inductive reactance and capacitive reactance do not dissipate actual power in a circuit. Real power is dissipated only in resistance.

Q. 2. DEFINE WHAT IS MEANT BY THE TIME CONSTANT IN A RESISTANCE-CAPACITANCE CIRCUIT. HOW IS THE TIME CONSTANT DETERMINED?

A. The time constant of a resistance-capacitance circuit is the time in seconds that it takes for the capacitor to charge up to 63.2% of the applied voltage. The formula for determining the time-constant is:

$$T = R \times C$$

where T is the time constant in seconds, R is the resistance in ohms and C is the capacitance in farads.

Q. 3. WHAT DOES THE TERM "POWER FACTOR" MEAN IN REFERENCE TO ELECTRIC POWER CIRCUITS?

A. Power factor is the ratio of the true power as measured by a wattmeter to the apparent power as computed by multiplying the voltmeter reading and the ammeter reading. In an AC circuit, the true power is always less than the apparent power. This is so because the voltage and current are out of phase, and there are times during each cycle when current is being sent back into the source.

Q. 4. HOW DO MICA AND PAPER DIELECTRIC BYPASS CAPACITORS COMPARE AT DIFFERENT FREQUENCIES?

A. For effective bypassing at power frequencies, audio frequencies and low RF frequencies, paper dielectric capacitors are usable. How-

ever, at short wave RF frequencies, paper capacitors are not adequate. Their effective capacitance is considerably reduced at the higher frequencies.

On the other hand, mica dielectric is excellent at the higher frequencies. Mica capacitors exhibit low losses at high frequencies and are, therefore, excellent for use as bypass capacitors at those frequencies.

Q. 5. WHAT MUST THE VALUE OF AN INDUCTOR BE TO CANCEL A CAPACITIVE REACTANCE OF 12.6 KILOHMS AT AN OPERATING FREQUENCY OF 2 MC/S.?

A. The inductive reactance must be 12.6 kilohms since it must be equal to the capacitive reactance in order to cancel it. To find the inductance, we set up the formula for inductive reactance and solve for the inductance.

$X_L = 2\pi fL$, $L = \frac{X_L}{2\pi f}$ where: X_L is inductive reactance in ohms, π is 3.14 and f = frequency in cycles.

We then substitute the known given values to arrive at the value of L.

$$L = \frac{12,600}{2 \times 3.14 \times 2,000,000} = \frac{12,600}{12,560,000} \text{ or } .001 \text{ H or } 1 \text{ mh.}$$

VACUUM TUBES

Q. 6. LIST SEVERAL ADVANTAGES AND DISADVANTAGES EACH FOR CLASS A, CLASS B AND CLASS C AMPLIFIER OPERATION.

A. In a Class A amplifier, the tube is biased in the middle of the straight line portion of its characteristic curve. The grid drive is low and plate current flows during the entire input cycle. These characteristics result in excellent reproduction of the input signal at the output and poor efficiency - approximately 20 to 30%. Since the grid does not draw current, the driving power is almost zero.

In a Class B amplifier, the tube is biased at approximately the cut-off point. Some grid driving power is required since the grid draws current. Plate current flows during one half of the input cycle, resulting in a greater efficiency (50 to 70% at audio frequencies) than the Class A amplifier. Since the plate current does not flow during the entire cycle, the fidelity of a Class B amplifier is not as good as a Class A amplifier. If we use Class B amplification in an audio circuit, two tubes are required so that both halves of the input cycle can be reproduced.

In a Class C amplifier, the tube is biased considerably beyond the cut-off point. Plate current flows for approximately one-third of the input cycle, resulting in the highest efficiency of the three types (60 to 80%). We have the poorest fidelity because only a fraction of the input signal is reproduced. Thus, we cannot use a Class C amplifier for audio amplification. The grid is driven positive, necessitating a high grid drive.

When the Class B and Class C amplifiers are used in RF power service, the plate tuned circuit compensates for the distortion generated in the tube by storing energy when the tube is drawing current and delivering the stored power when the tube is cut off.

Q. 7. WHAT VISUAL OBSERVATION WITHIN AN OPERATING

VACUUM TUBE'S ENVELOPE WOULD INDICATE THAT THE TUBE IS GASEOUS?

A. A gassy tube usually shows a blue or purple haze between the cathode and the plate. Also, the plate may become red.

POWER SUPPLIES AND FILTERS

Q. 8. DISCUSS THE ADVANTAGES AND DISADVANTAGES OF ELECTROLYTIC VERSUS PAPER FILTER CAPACITORS.

A. Some of the advantages of electrolytic capacitors over paper capacitors are: A large amount of capacitance in a small amount of space, low cost for a given amount of capacitance, self-healing after breakdown caused by temporarily exceeding voltage maximums.

Some of the disadvantages of electrolytic capacitors are: Can only be used in DC circuits, polarity must be observed, low voltage ratings (if used in high voltage circuits, capacitors must be in series and equalizing resistors must be placed across them), capacitance varies with voltage, high accuracy in value cannot be had.

Some advantages of paper capacitors over electrolytic capacitors are: Can be used in AC or DC circuits, no polarity need be observed, can be made to take higher voltages than electrolytic capacitors, can be made with very accurate values.

Some disadvantages of paper capacitors are: Large bulk for a small amount of capacitance, expensive for a large amount of capacitance, not self-healing if the dielectric has been punctured.

Q. 9. HOW DO FILTERS ATTENUATE HARMONIC EMISSIONS?

A. A low pass filter, placed between the output of the transmitter and the antenna, will considerably reduce harmonic emission. The harmonic emissions are multiples of the fundamental frequency that is being transmitted. In other words, if we are transmitting at 29 Mc., the unwanted harmonics will occur at 58 Mc., 87 Mc., 116 Mc., etc. If we use a low pass filter with a cut-off frequency of 40 Mc., it will pass the 29 Mc., but it will attenuate most of the energy above 40 Mc. Thus, the harmonics of 58 Mc., 87 Mc., 116 Mc., etc. will not be able to get through to the antenna.

Q. 10. DESCRIBE BRIEFLY HOW AN AC POWER SUPPLY PRODUCES A DC OUTPUT VOLTAGE. DISCUSS THE MERITS OF USING CHOKE-INPUT VERSUS CAPACITOR-INPUT FILTERS IN POWER SUPPLIES. HOW DOES THE LEAKAGE RESISTANCE OF THE CAPACITORS AFFECT THE OUTPUT VOLTAGE? ALSO, WHAT IS VOLTAGE REGULATION AS RELATED TO POWER SUPPLIES?

A. Fig. 10A illustrates a half-wave AC power supply. AC is applied to the "AC input" terminals. The transformer steps up the AC voltage and applies it to the diode. AC reverses its direction periodically. However, the diode only allows current to flow through it in one direction, the direction of the arrows. The diode blocks every other alternation and current will flow through the load in only one direction. Thus, DC has been produced. The purpose of the filter in Fig. 10A (C_1, C_2 and L) is to smooth out the pulsating DC into pure DC.

We call the filter of Fig. 10A a capacitor-input filter because its

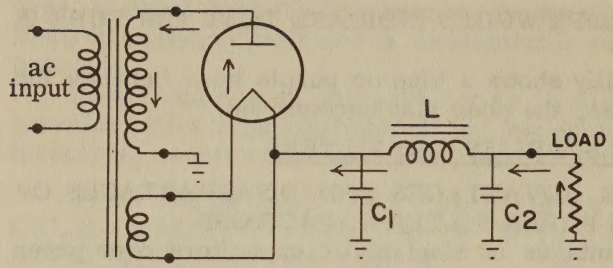

Fig. 10A.
A half-wave AC power supply.

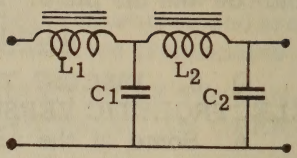

Fig. 10B.
A choke input filter.

first component is a capacitor (C_1). A capacitor-input filter is known for its higher output voltage and poorer voltage regulation, as compared to a choke-input filter. Fig. 10B shows a choke-input filter. Note that its first component is a choke. Compared to the capacitor input filter, the choke input filter has better voltage regulation and a lower output voltage.

If the filter capacitor has too much leakage, it will draw additional current and tend to reduce the output voltage. Also, if it has more than normal leakage, its capacitance is reduced and it will not filter properly.

Voltage regulation indicates the amount of output B+ voltage variation of a power supply as the load changes. A power supply that has good voltage regulation is one whose B+ voltage changes very little under varying load conditions.

Q. 11. COMPARE SILICON AND VACUUM TUBE DIODES. WHAT IS MEANT BY THE "FORWARD VOLTAGE DROP" OF A CONDUCTING SILICON DIODE?

A. A silicon diode is compact and light in weight, as compared to a vacuum tube diode. Since the silicon diode does not contain a filament, its operation is instantaneous and it does not require a filament transformer. The silicon diode has a lower internal voltage drop than a vacuum tube diode and therefore, has less internal power dissipation.

An important disadvantage of the silicon rectifier is that it has a low peak inverse voltage rating which must not be exceeded. In general, vacuum tube diodes can tolerate temporary voltage peaks that exceed the tube's ratings without damage. The silicon diode is more delicate in this respect and should have a special circuit for protection.

The "forward voltage drop" of a conducting silicon diode is the voltage drop across the diode while it is conducting in the proper direction.

AF AND RF AMPLIFIERS

Q. 12. WHAT IMPROPER OPERATING CONDITIONS ARE INDICATED BY THE UPWARD OR DOWNWARD FLUCTUATION OF A CLASS A AMPLIFIER'S PLATE CURRENT WHEN A SIGNAL VOLTAGE IS APPLIED TO THE GRID? HOW CAN THIS BE CORRECTED?

A. In a properly operating Class A amplifier, the average plate current remains the same when a signal is applied to the grid. This is because the tube is operating in the middle of the straight line portion

of the IpEg curve and the signal causes equal plate current variations above and below the "no signal" plate current point. The average current, therefore, remains the same.

If the grid bias is too high, the operating point will shift to the lower curved portion of the I_pE_g curve. The average plate current will rise because part of the negative portion of plate current variation will be cut off. If the grid bias is too low, the operating point will shift to the upper curved portion of the IpEg curve. The average plate current will fall because part of the positive portions of the plate current variations will be cut off. Excessive drive will cause either an increase or decrease in plate current, depending upon the exact amount of bias, the shape of the IpEg curve, and other factors.

To correct the above problems, use the proper amount of grid bias for the plate and screen voltages and hold the peak drive to less than the grid bias voltage. Also, use the proper tube and the right voltages on the tube elements.

Q. 13. WHAT IMPROPER OPERATING CONDITIONS ARE INDICATED BY GRID CURRENT FLOW IN A CLASS A AMPLIFIER?

A. Grid current will flow when the grid of a tube is positive with respect to the cathode. There is no grid current in the normal operation of a Class A amplifier. If grid current flows only when a signal is applied, it indicates that the signal is greater in peak amplitude than the grid bias. This can be due to excessive signal or incorrect bias adjustment.

If there is no signal applied and there is a steady grid current flow, it is probably due to the leakage through the coupling capacitor from the previous stage, or the tube may be gassy.

Q. 14. DEFINE THE TERM DECIBEL. HOW IS THE DECIBEL USED FOR VOLTAGE AND POWER CALCULATIONS?

A. The decibel (db) is a unit used to express a ratio between two power, current or voltage levels in sound and electrical work. The decibel, as shown by the formula, is a logarithmic unit. This is used because our impression of loudness is proportional to the logarithm of the sound energy and not to the energy itself. For example, if a sound were increased in energy to 1000 times its original value, it would only appear to the ear to be 30 times as loud. In other words, the decibel is a comparison of power levels with respect to our hearing. The formulas for determining power or voltage gains or losses are as follows:

$$db = 10 \log \frac{P_2}{P_1}, \quad db = 20 \log \frac{E_2}{E_1} \quad db = 20 \log \frac{I_2}{I_1}$$

where P_2, E_2 and I_2 represent the larger power, voltage and current, respectively, and P_1, E_1 and I_1 represent the smaller power, voltage and current, respectively.

When the ratio that is expressed in decibels is for an increase in level or gain, it is considered positive. When it is for a decrease in level, or loss, it is considered negative and written with a minus sign before the number, such as, -24.3 db.

Q. 15. WHAT ARE SOME CAUSES OF THE EXCESSIVE PRODUC-

TION OF HARMONICS IN RF AMPLIFIERS? HOW CAN THESE CAUSES BE REMEDIED?

A. Some of the causes of excessive production of harmonic radiation are:

(1) Improper bias. Excessive bias will cause a high harmonic output.

(2) Grid drive too high. Excessive grid drive causes a high harmonic output.

(3) Capacitive coupling. The use of capacitive coupling allows for the transfer of harmonics from one stage to the next.

(4) Tight coupling between coils will allow harmonic energy to be transferred.

(5) Insufficient shielding will permit harmonics to be radiated.

Excessive production of harmonics can be remedied by:

(1) Use a Faraday shield. A Faraday shield between two inductively coupled coils will reduce the capacitive coupling through which harmonics are transferred.

(2) Use a low-pass filter between the transmitter and the antenna. The low pass filter will pass the desired signal and stop the harmonic frequencies from passing.

(3) Use proper bias. The bias should be correct for the class of operation used to obtain the best harmonic attenuation.

(4) Use proper grid drive. The drive from the previous stages should be as low as possible.

(5) Use high Q plate tank circuits. High Q circuits are highly selective and will efficiently pass the desired signal and attenuate the harmonics.

(6) Use link coupling. When a link is added to a tuned L-C circuit, a transformer is formed. A high degree of harmonic attenuation results because most of the energy transfer will be due to the magnetic coupling at the resonant frequency of the L-C circuit.

(7) Avoid capacitive coupling. Since a capacitor offers a decreasing impedance at the higher frequencies, there is little opposition to the high frequency harmonics.

(8) Use tuned circuits. Tuned circuits are more effective at harmonic attenuation than R-C coupling circuits due to their frequency selecting characteristics.

Q. 16. HOW ARE GROUNDED-GRID AMPLIFIERS USED IN ELECTRONIC CIRCUITS? LIST SOME ADVANTAGES AND DISADVANTAGES OF THEIR USE. DESCRIBE THE INPUT IMPEDANCE CHARACTERISTICS OF A GROUNDED-GRID AMPLIFIER.

A. (a) The grounded grid amplifier operates in much the same manner as the ordinary grounded cathode amplifier. The principal difference is the fact that the grid is grounded for signal frequencies. The grid bias requirements are normal. The signal voltage is applied between cathode and grid. This causes the plate current to vary and the amplifier output is taken from the plate, using normal circuitry.

(b) ADVANTAGES:

(1) Inherent stability. Neutralization is seldom needed as the

grounded grid acts as a shield between the output (plate) and the input (cathode). This reduces the feedback capacity to about one-twenty-fifth of the grid-to-plate capacitance of the same tube in a grounded cathode circuit.

(2) The output capacity is about one-half of that in a grounded cathode circuit. This permits operation at much higher frequencies.

(3) The grounded grid amplifier is satisfactory for use as a linear amplifier for AM, SSB and TV service, or as a conventional amplifier for FM and CW operation.

(4) When used in a receiver as an RF amplifier, the grounded grid amplifier is capable of a better noise figure than the usual pentode. It can be used at much higher frequencies than a pentode.

DISADVANTAGES:

(1) The driving power required is very high as the input impedance is quite low.

(2) In a grounded grid amplifier, the full excitation voltage appears between the cathode and ground. This makes it necessary to use large RF chokes, or other means, to isolate the filament and cathode from ground.

(3) A grounded grid amplifier cannot be 100% plate modulated unless the driver is also modulated about 70%.

(c) The input impedance of a grounded-grid amplifier is low and, in many applications, requires a large amount of driving power.

Q. 17. WHY IS THERE A PRACTICAL LIMIT TO THE NUMBER OF STAGES THAT CAN BE CASCADED TO AMPLIFY A SIGNAL?

A. There are two factors that limit the number of stages in an amplifier:

(1) Too many stages will increase the gain high enough to cause instability. This will result in oscillation and distortion.

(2) If the gain is too high, the noise that is generated in the first stages can degrade the signal to noise ratio seriously.

Q. 18. WHAT IS PUSH-PULL AMPLIFIER OPERATION?

A. Fig. 18 shows two tubes connected as a push-pull Class A amplifier. Two input signals are required. They must be identical in magnitude, but 180° out of phase with each other. The signals can be developed by phase inverters or by a center-tapped driver transformer.

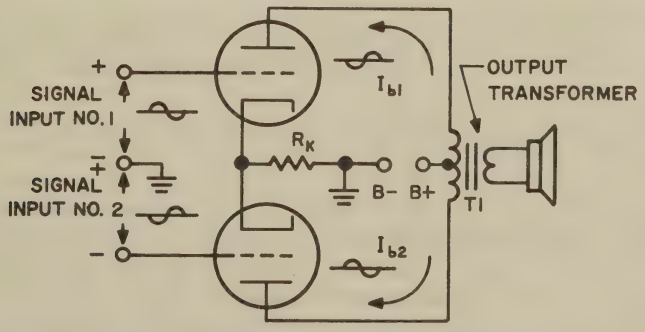

Fig. 18. A push-pull Class A amplifier.

These input signals drive the grid of one tube positive, while the grid of the second tube is being driven negative. Thus, as the plate voltage of one tube is going more negative, the plate voltage of the second tube is going more positive. The output voltages of the two tubes add in the output transformer.

Some advantages of push pull circuits over single ended circuits are: Less distortion because even order harmonics are cancelled, less chance of core saturation since DC currents flow in opposite directions in the primary of the output transformer, ripple voltages from the power supply tends to cancel since they flow in opposite directions in the primary of the transformer.

MODULATION

Q. 19. WHAT ARE SIDEBAND FREQUENCIES? DURING 100% SINUSOIDAL AMPLITUDE MODULATION, WHAT PERCENTAGE OF THE AVERAGE POWER IS IN THE SIDEBANDS? HOW IS THE SIDEBAND POWER RELATED TO THE PERCENTAGE OF MODULATION?

A. Sideband frequencies are the new frequencies that result when an RF carrier is modulated by an audio signal. Whenever any two frequencies combine by modulation, the resultant signal will contain the original frequencies, plus the sum and difference of the original frequencies. The new sum and difference frequencies are known as sideband frequencies, or simply sidebands. For example, if a 2 kc. audio signal were to modulate a 1000 kc. carrier, the resultant signal would contain (in addition to the 2 kc. and 1000 kc. frequencies), 1002 kc., known as the upper sideband, and 998 kc., known as the lower sideband.

During 100% sinusoidal amplitude modulation, 33-1/3% of the average power is in the sidebands. This is because the modulator must supply an audio output equal to 50% of the carrier input power to achieve 100% sinusoidal modulation. Thus, if a 100 watt carrier is modulated by 50 watts of audio, the total power is now 150 watts and 50 watts is 33-1/3% of 150 watts.

As the percentage of modulation increases, the sideband power increases, and vice versa. The audio modulating voltage is directly proportional to the percentage of modulation. Since power is proportional to the square of the voltage, the sideband power is proportional to the square of the percentage of modulation.

Q. 20. WHAT WOULD HAPPEN IF THE GRID-BIAS SUPPLY OF A CLASS C MODULATED AMPLIFIER WAS SUDDENLY SHORT-CIRCUITED?

A. If the grid-bias supply of a Class C modulated amplifier was short-circuited, the plate current would rise and possibly damage the tube. The grid-bias supply keeps the control grid negative with respect to the cathode. If we remove this negative potential on the grid, the plate current will not be impeded by a negative grid and will rise. If there is no cathode bias to act as a safety bias, the high plate current will probably overheat and damage the tubes.

Q. 21. WHAT IS A GRID-BIAS MODULATED AMPLIFIER? SHOULD

THE SOURCE OF FIXED BIAS HAVE A HIGH OR LOW INTERNAL RESISTANCE? EXPLAIN.

A. A grid bias modulated amplifier is one in which the audio frequency signal is combined with the RF signal by varying the grid bias with the audio signal. The fixed DC grid bias source should have a minimum of resistance. If the internal resistance of the bias supply is too high, the fixed portion of the bias voltage will change with modulation, causing distortion.

Q. 22. WHAT DO THE MODULATION ENVELOPES OF AMPLITUDE-MODULATED WAVES WITH 75%, 100% AND GREATER THAN 100% MODULATION LOOK LIKE?

A. Fig. 22 illustrates amplitude modulated waves of 75%, 100% and greater than 100% modulation.

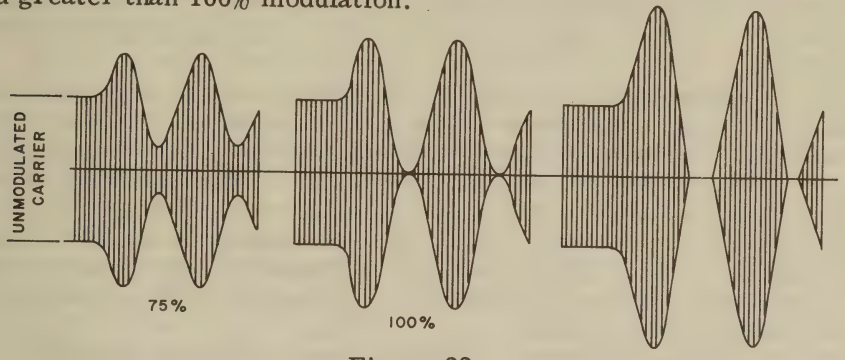

Figure 22.

Q. 23. WHAT MAY BE THE CAUSE OF A DECREASE IN ANTENNA CURRENT DURING MODULATION OF A CLASS B R. F. AMPLIFIER?

A. A Class B amplifier is used in RF service almost entirely as a linear amplifier and not as a modulated amplifier. Modulation of the plate supply voltage of a Class B amplifier cannot be used to obtain high percentages of modulation without severe distortion. We can reduce this distortion somewhat by modulating the driver stage at the same time. However, this is not usually done except in some solid state equipment. When modulation is to be used, a Class C amplifier is the usual choice.

When an amplitude modulated signal is passed through a Class B linear amplifier, the antenna current will decrease if the plate loading is too light. Distortion, incorrect tuning or biasing of the preceding stages can also cause decreased antenna current. In a SSB transmitter using a Class B amplifier, there is no output until modulation is applied. Therefore, the antenna current cannot decrease from the unmodulated condition.

Q. 24. WHAT ARE THE BANDWIDTHS NORMALLY USED FOR A1, A3 (SINGLE AND DOUBLE SIDEBAND), AND F3 (NARROWBAND) TYPE EMISSIONS?

A. A1 is a CW signal. It has no modulation and therefore, occupies almost no bandwidth. Technically speaking, it could occupy up to 150 cycles, the exact amount depending mainly upon the code speed.

A3 refers to amplitude modulated telephony. A single sideband signal occupies a bandwidth equal to the highest audio frequency that modulates the carrier. A double sideband signal occupies a bandwidth twice that of the single sideband signal. Normal bandwidths for single and double sideband would be approximately 3 kc. and 6 kc., respectively.

F3 stands for frequency modulation. In accordance with FCC regulations, the bandwidth of an F3 emission shall not exceed that of an A3 emission having the same audio characteristics. The maximum bandwidth of F3 emission must therefore be 6 kc., the same as A3 (double sideband). We refer to this as narrow band FM.

Communications services above 400 Mc. use a bandwidth of 30 kc.

TRANSMITTERS

Q. 25. HOW CAN A TRANSMITTER BE TESTED FOR SELF-OSCILLATION? WHAT PRECAUTIONS SHOULD BE OBSERVED DURING TESTING?

A. In testing a transmitter for self-oscillation, we first tune it up normally. We then remove the crystal, or otherwise "kill" the exciting signal. The transmitter is keyed and if we see grid current and/or RF output, we know that self-oscillation is present. We check with the tuning controls in all positions. In many transmitters, there is a high risk of overloading and damaging tubes and components if the key is held down too long. The transmitter should be keyed for only a few seconds at a time during this test. It should be allowed to cool down for longer periods than the keying time.

To localize the unstable circuit that causes the self-oscillation, it is necessary to disable all but the suspected circuits. In a typical AM/CW transmitter consisting of an oscillator/multiplier, a driver and a final amplifier, the procedure would be as follows: The most likely source of trouble is in the final amplifier. To isolate this stage, it is only necessary to remove the driver tube and repeat the tests, tuning the grid, plate and loading controls to all positions and combinations while keying for very short periods, as above. If there are no grid current or plate current jumps or RF output, this stage is probably stable. Put the driver tube back in place and remove the oscillator multiplier tube. Repeat the test, tuning any other control that is now in the circuit. Usually, this would be the oscillator plate tuning capacitor and possibly a drive control. If there are no grid current or plate current jumps or RF output, the driver and final are both probably stable. With all three tubes in place, but no drive or crystal used, repeat the tests. If there are no indications, as above, the transmitter is stable.

When an indication of oscillation is found, it is necessary to localize the cause. In a new transmitter design, check the following: Is the shielding between the grid and plate of the unstable stage satisfactory? Will the addition of a parasitic suppressor in the plate and/or grid lead stabilize it? Is neutralization necessary? If it is neutralized, is the adjustment of the neutralizing circuit correct? Is the tube good? Is there any path that a signal can follow from output to input, over one or more stages, such as a filament, B+ or control line? Additional bypassing and filtering of such lines may be necessary.

The frequency of the oscillation can be identified by use of a general coverage receiver or a grid-dip oscillator used as a wave meter. The frequency is often far above or below the operating frequency of a transmitter. As an example, when a grid choke and a plate choke in the same stage are of the same value, the circuit will very likely work as a tuned grid-tuned plate oscillator at a frequency determined by the RF chokes and the capacities in the circuit. Parasitics are often up in the VHF or UHF range, controlled by the leads from the tubes to the tuning capacitors. In this case, the tank coil appears as a large inductance RF choke and has no effect on the frequency of oscillation. This is usually corrected by adding a parasitic suppressor in the plate line of the tube.

Q. 26. HOW CAN THE OUTPUT CIRCUIT OF A TRANSMITTER BE ADJUSTED TO INCREASE OR DECREASE ITS COUPLING TO THE ANTENNA SYSTEM?

A. In a transmitter using a pi-network between the final amplifier and the antenna, the coupling can be varied by adjustment of the output capacitor in the pi-network. The normal adjustment sequence is to start with more capacity than is needed in the output capacitor. We then resonate the plate tuning capacitor and decrease the output (or loading) capacitor. We again resonate the plate capacitor. The sequence is repeated until the desired conditions are met. The tuning can be for maximum RF output or for the proper dip in the plate current in the final amplifier. If less output is desired, the adjustments can be left at an intermediate point, where the output capacitor is at a higher value than normal.

Where link coupling (with a series capacitor) is used, the link is adjusted when the equipment is first installed and left fixed. The plate tuning and link capacitor are adjusted in the same manner as the pi-network plate and loading capacitors above. If there is no capacitor in series with the link, the link's relation to the plate tank coil is usually adjustable by a front panel control. The adjustment sequence is to move the link almost out of the tank coil and then tune the plate capacitor for the proper plate current dip or maximum RF output. The link is moved into the plate coil slightly and the plate capacitor retuned. This cycle is repeated until the proper dip in plate current or the maximum power output is obtained. In all cases, when the tuning is completed, it is necessary to check the plate current to see that the tube is not being operated above its ratings.

Q. 27. HOW CAN PARASITIC OSCILLATIONS BE PREVENTED?

A. Parasitic oscillations are not easy to cure. One or more of the following must be tried in order to eliminate the parasitic oscillation:

(1) Insert a small non-inductive resistor in series with the plate and/or grid of the stage where the oscillations occur.

(2) Change the "dress" of the leads in the stage where the parasitic oscillations originate. Shielding some leads may be necessary.

(3) Insert low value RF chokes in series with the plate and/or screen leads.

(4) Insert low value RF chokes shunted by low value resistors in series with the plate lead and/or grid lead.

(5) Heavily bypass points in the circuit that should be "cold" to RF.

Q. 28. GIVE SOME PROVEN METHODS OF HARMONIC REDUCTION IN TRANSMITTERS.

A. The following measures can be used to reduce the generation of harmonics:

(1) Use a Faraday shield. A Faraday shield between two coils will reduce the capacitive coupling through which harmonics are transferred.

(2) Use a low-pass filter between the transmitter and the antenna. The low pass filter will pass the desired signal and stop the harmonic frequencies from passing.

(3) Use proper bias. The bias should be as low as possible for best harmonic attenuation.

(4) Use proper grid drive. The drive from the previous stages should be as low as possible.

(5) Use high Q plate tank circuits. High Q circuits are highly selective and will efficiently pass only the desired signal, not the harmonics.

(6) Use link coupling. When a link is added to a tuned L-C circuit, a transformer is formed. A high degree of harmonic attenuation results because most of the energy transfer will be due to the magnetic coupling at the resonant frequency of the L-C circuit.

(7) Avoid capacitive coupling. Since a capacitor offers a decreasing impedance at the higher frequencies, there is little opposition to the high frequency harmonics.

(8) Use tuned circuits. Tuned circuits are more effective at harmonic attenuation than capacitor coupling circuits, due to their frequency selecting characteristics.

Q. 29. HOW MAY AN AMATEUR CHECK HIS TRANSMITTER FOR SPURIOUS SIDEBANDS?

A. Spurious sidebands are caused by distortion products generated in the transmitter which occur outside of the channel that a signal normally occupies. An amateur may determine whether he is transmitting spurious sidebands by tuning his receiver to both sides of the signal. Normally he should hear nothing. If he is transmitting spurious sidebands, he will generally pick up a badly distorted version of his signal, or possibly clicks. In making this test, the receiver should be some distance from the transmitter and the receiver's antenna should be disconnected to prevent overload in the receiver. A good quality, highly selective receiver should be used and its RF gain control should be at a low level.

Q. 30. WHAT RADIOTELEPHONE TRANSMITTER OPERATING DEFICIENCIES MAY BE INDICATED BY A DECREASING ANTENNA RF CURRENT DURING MODULATION OF THE FINAL RF AMPLIFIER?

A. A drop in the antenna current in a plate modulated RF amplifier can be caused by the following:

(a) Grid bias is too low.

(b) RF excitation is inadequate.

(c) The load impedance is incorrect.

(d) The plate power supply for the amplifier has inadequate regulation.

A drop in the antenna current in a grid-bias modulated RF amplifier

can be caused by the following:

(a) Excessive RF excitation.

(b) Grid bias is too low.

(c) Resistance in grid bias supply is too high.

(d) Plate tank is inadequately loaded. (Load impedance is too high).

(e) Modulator and/or speech amplifier is generating excessive distortion.

ANTENNAS AND PROPAGATION

Q. 32. DESCRIBE BRIEFLY SOME WELL KNOWN TYPES OF ANTENNAS AND ANTENNA SYSTEMS USED BY AMATEURS WHICH DO, AND DO NOT, REDUCE HARMONIC RADIATION.

A. Antennas that are resonant will reduce the harmonic radiation at all or at least some harmonics. Random length antennas can be regarded as resonant antennas in which the resonant frequencies are unknown. Some resonant antennas are: the dipole, usually 1/2 wave, the yagi, the quarter wave, the quad, the collinear and the ground plane.

Broad band antennas can be used over a wide range of frequencies and many of these not only do not reduce harmonic radiation, but are more efficient as the frequency increases. Some antennas in this class are: the log periodic, the rhombic, the "V" or inverted "V", the discone, the horn, the parabolic and the conical. In the cases of the horn and parabolic antennas, the radiating device is often a resonant type antenna; however, the complete antenna cannot be considered resonant.

Q. 33. WHAT DETERMINES THE SKIP DISTANCE OF RADIO WAVES?

A. The skip distance of radio waves is determined by many factors. Among the important ones are:

(1) The frequency of the radio wave.

(2) The height of the ionosphere layer above earth.

(3) The density of the ionosphere layer.

(4) The time of day.

(5) The time of year.

(6) The level of sunspot activity.

(7) The number of reflections from the ionosphere.

Note that 4, 5 and 6 affect 2 and 3.

Q. 34. LIST SOME DIFFERENT TYPES OF BEAM ANTENNAS.

A. A "beam antenna" is a broad term used to designate an antenna array consisting of two or more antenna elements or wires. Its purpose is to radiate maximum energy in one or more directions. Some different types of beam antennas are:

(1) Yagi antenna. One driven element and one or more parasitic elements, all in the same plane. See Answer 36. It is unidirectional.

(2) Collinear. Two or more half-wave driven elements in a straight line, end to end. A collinear array consists of several collinear antennas mounted parallel to each other, with either a screen or an equal number of parasitic reflector elements behind the driven antenna elements.

(3) Broadside. Two or more half-wave driven elements, placed parallel to one another, at right angles to the direction of transmission. A broadside array can consist of a number of groups of radiators as

above, with or without reflectors. Directors can also be used on either collinear or broadside antennas.

(4) "V" beam antenna. Two wires combined at the proper angle in the shape of a V. The ends may be terminated or unterminated.

(5) Rhombic or Diamond antenna. An extension of the V beam. The wires form a rhombus.

(6) Loop antenna. A loop antenna is a radiating coil of one or more turns. The pattern is that of a dipole, namely a figure 8. With the addition of a non-directional antenna and the signals properly combined in the receiver, the pattern becomes unidirectional, a cardioid. The single null is useful for direction finding as it eliminates the 180° ambiguity of the loop alone.

(7) Cubical Quad. A pair of square loops, one being the driven element and the other the reflector. The sides are one-quarter wavelength long. More than two elements can be used.

Q. 35. WHAT ARE AURORA-REFLECTED VHF SIGNALS? IF SUCH A SIGNAL IS HEARD, WHAT DOES IT SOUND LIKE?

A. VHF signals are often reflected by the ionized gases in an aurora display in the sky. The character of the signal is very much distorted as the reflecting surface is varying in a random fashion. This produces multipath and Doppler disturbances. Amplitude modulated signals are often completely distorted and unreadable. Code signals sound like a hoarse hiss, but when sent at a reasonably slow speed, are quite readable. SSB voice signals lack all the low frequency components and sound like a hoarse, rasping whisper. Readability is fairly good if the operator speaks very slowly.

Q. 36. WHAT CONSTITUTES A PARASITIC ANTENNA ELEMENT?

A. A transmitting beam antenna consists of a driven element and one or more parasitic elements, all in parallel to each other and in a plane. A four-element beam is shown in Fig. 36. DE is the driven element and R, D1 and D2 are the parasitic elements.

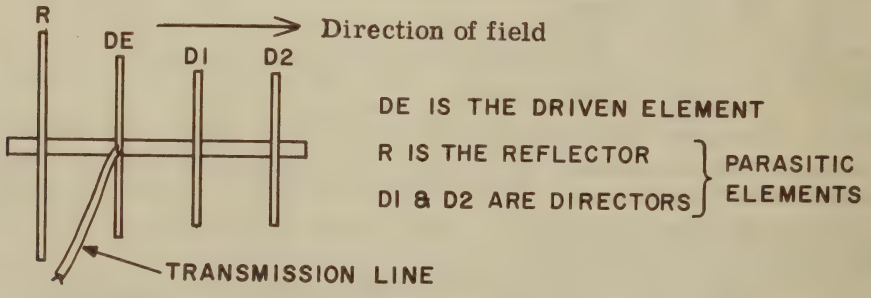

Figure 36.

The driven element receives its power directly from the transmitter through the transmission line. It then radiates its energy in the form of an electromagnetic field. The parasitic elements are not electrically attached to the driven element or to the transmitter. The electromagnetic radiation from the driven element cuts the parasitic elements and

induces energy into them. The parasitic elements then re-radiate electromagnetic energy. The driven element and the parasitic elements are tuned by adjusting their lengths. The combined fields from the driven element and the parasitic elements form the desired radiation pattern. Note the direction of the field of the beam in Fig. 36. The two elements in "front" of the driven elements are called directors. Their lengths are slightly less than that of the driven element. The element "behind" the driven element is called a reflector and it is slightly longer than the driven element.

Q. 37. HOW DOES THE DIRECTIVITY OF AN UNTERMINATED "V" ANTENNA AND PARASITIC BEAM ANTENNA COMPARE?

A. A parasitic beam antenna is unidirectional, that is, it transmits

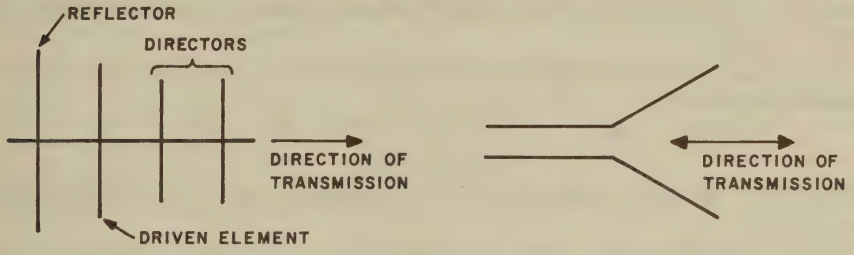

Figure 37.

and receives well in one direction. An unterminated "V" antenna is bidirectional; it receives and transmits well in two directions. The directivity of the two antennas is shown in Fig. 37.

Q. 38. WHAT IS MEANT BY "END EFFECTS" IN AN ANTENNA? HOW CAN THEY BE COMPENSATED FOR IN HALF WAVE ANTENNAS?

A. "End effects" are electrical factors occurring at the ends of an antenna that cause an antenna to be electrically longer than its physical measurement would indicate. These "end effect" factors are due mainly to the additional capacitance of the insulators supporting the ends of the antenna and also to the fact that the electrical field distribution at the end of the antenna is different than that at its center. End effects become more pronounced as the frequency increases.

We can compensate for these "end effects" in a half wave antenna by reducing its length by an average of 5%, the exact amount depending upon the frequency, thickness of the elements, type of antenna, etc.

Q. 39. WHAT EFFECT DOES A TRANSMISSION LINE WHICH IS NOT PROPERLY TERMINATED HAVE ON THE PLATE TANK CIRCUIT OF A TRANSMITTER?

A. In order to have maximum power transfer between the output tank circuit and the antenna, the impedance of the tank circuit must match the impedance of the transmission line. Furthermore, the impedance of the transmission line must match the impedance of the antenna. If there is a mismatch at the antenna end, it will affect the im-

pedance of the transmission line at the transmitter end. The impedance of the transmission line will no longer be equal to the impedance of the tank circuit and there will be a reduction in output power, as well as difficulty in loading.

A mismatched line will also introduce a reactive element into the tank circuit and it will be difficult to tune the final plate circuit. If the reactance that is introduced is high, the normal tuning controls may not be able to compensate for this change and tuning may be impossible.

Q. 40. A 70 OHM TRANSMISSION LINE IS CONNECTED TO A 35 OHM ANTENNA. CALCULATE THE STANDING WAVE RATIO (SWR), THE REFLECTION COEFFICIENT, AND THE PERCENT REFLECTED POWER. IF 10 AMPERES ARE FLOWING IN THE ANTENNA TERMINALS, WHAT IS THE CURRENT IN A TRANSMISSION LINE NODE? HOW IS THE SWR RELATED TO THE FORWARD AND REVERSE CURRENT FLOW?

A. (a) The standing wave ratio (SWR) is 2 (or 2 to 1). It is calculated as follows:

$$SWR = \frac{Z_{line}}{Z_{load}} \text{ or } \frac{Z_{load}}{Z_{line}} = \frac{70}{35} = 2$$

where Z_{line} is the transmission line impedance and Z_{load} is the antenna impedance.

Note that since the SWR is always unity or greater, we use the formula that has the larger impedance as the numerator.

(b) The reflection coefficient is the ratio of the reflected voltage or current to the original (forward) voltage or current. It can be determined by the following formula:

$$K = \frac{SWR-1}{SWR+1} = \frac{2-1}{2+1} = \frac{1}{3} \text{ or } 0.333$$

where K is the reflection coefficient and SWR is the standing wave ratio.

(c) The percentage of reflected power can be determined by the following formula:

$$\% PR = \left(\frac{SWR-1}{SWR+1}\right)^2 \times 100 = \left(\frac{2-1}{2+1}\right)^2 \times 100 = \left(\frac{1}{3}\right)^2 \times 100 = 11\%$$

The percentage of reflected power is, therefore, 11%.

(d) The current at the antenna terminals is the highest in the antenna system because the resistance at this point is the lowest in the antenna system. Since the standing wave ratio is equal to the maximum current over the minimum current, the minimum current or node, as it is sometimes called, is equal to 5 amps. This can be seen by the SWR formula for current:

$$SWR = \frac{I_{max.}}{I_{min.}} \qquad 2 = \frac{10 \text{ A.}}{I_{min.}} \qquad I_{min.} = 5 \text{ A.}$$

The higher the SWR, the greater will be the reverse current flow compared to the forward current flow. The lower the SWR, the lower will be the reverse current flow compared to the forward current flow. The relationship between these factors is given by the following formula:

$$SWR = \frac{I_F + I_R}{I_F - I_R}$$

where: I_F is forward current flow and I_R is reverse current flow.

Q. 41. WHAT ARE CURRENT AND VOLTAGE CHARACTERISTICS ALONG A TRANSMISSION LINE WHEN IT IS MATCHED AND MISMATCHED?

A. If a transmission line is properly matched to the transmitter and to the antenna, the current and voltage will be the same at all points on the transmission line. There will be no standing waves or reflections along the line.

If the transmission line is not terminated by an impedance equal to its own impedance, there will be a mismatch which will result in standing waves along the line. The voltage and current will vary from one point to another along the line. They will form a sine wave pattern on the transmission line.

Q. 42. CAN A LOSSY TRANSMISSION LINE BE USED TO TRANSMIT SIGNALS? EXPLAIN.

A. A lossy transmission line can mean two things: (1) a cable that is designed to have considerable loss for use as an attenuator or resistive termination device; or (2) it can be an inefficient transmission line that will radiate energy. The latter can be either incidental or it can be the basis for an antenna design. Both rhombic and folded dipole antennas are examples of transmission lines, modified to operate as radiators.

When an antenna is fed with a transmission line, there will always be some loss in the line. For example, if RG58/U is used at 1 Mc., the loss per 100 feet would be 0.24 db. At 100 Mc., it would be 4.1 db and at 1000 Mc., it would be 17.0 db. RG8/U would have losses of 0.13, 2.1 and 8.5 db respectively, at the same frequencies. RG17/U would have losses of 0.038, 0.85 and 4.0 db respectively. A 600 ohm open wire line would have losses of approximately 0.2 db per 100 feet at 100 Mc.

A 3 db loss means a power loss of 50%. It is often an economy to use a more expensive cable to feed the antenna.

Q. 43. EXPLAIN THE PROPERTIES OF A QUARTER-WAVE SECTION OF RF TRANSMISSION LINE. HOW WOULD THESE PROPERTIES CHANGE IF THE OUTPUT ENDS OF THE SECTION WERE SHORT-CIRCUITED.

A. A quarter-wave section of an RF transmission line exhibits different properties, depending upon how it is terminated. If it is terminated in an open circuit, it acts as a series resonant circuit and presents a low impedance at the other end. If it is terminated in a short circuit, it acts as a parallel resonant circuit and presents a high impedance at the other end. Thus we see that a quarter wave section of a transmission line "inverts" the impedance.

Quarter wave sections of transmission lines are commonly used as impedance matching devices.

OSCILLATORS

Q. 44. HOW CAN THE SAFE POWER INPUT TO A CRYSTAL OSCILLATOR CIRCUIT BE DETERMINED?

A. The safe power input to a crystal oscillator circuit is mainly dependent upon the amount of power that the crystal itself can handle

safely. This can be determined by measuring the RF voltage across the crystal, as well as the effective series resistance of the crystal. We can then calculate the power dissipated. The safe operating power level can be obtained from the manufacturer. It will usually be between 0.1 and 20 mw. An example will show how this information is used. Let us assume that a particular CR-18/U crystal, at 3.000 MHz, has a resonant resistance of approximately 175 ohms. The maximum safe power level is given as 5 mw. By using the power formula, we can determine the maximum voltage across the crystal.

$$P = \frac{E^2}{R} \text{ or } PR = E^2 \text{ or } E = \sqrt{PR} = \sqrt{.005 \times 175} = .93 \text{ V.}$$

Thus, the RMS voltage across the crystal must not exceed .93 V.

A less accurate way of determining whether the safe power rating of the crystal has been exceeded is by observing whether there is an excessive frequency drift. If the crystal power rating has been exceeded, the heat in the crystal will be high, causing the crystal's frequency to drift.

Q. 45. WHAT FACTORS DETERMINE THE FREQUENCY AT WHICH A QUARTZ CRYSTAL WILL OSCILLATE? LIST SOME OF THE ADVANTAGES OF USING CRYSTALS IN AMATEUR EQUIPMENT.

A. The fundamental frequency of a quartz crystal is mainly dependent upon its thickness. It is, to a lesser extent, dependent upon the angles at which the crystal blank was cut from the whole crystal, and also upon the temperature of the crystal.

The main advantage of a crystal is the high degree of frequency stability it provides when used in an oscillator. The use of a crystal helps insure operation of the amateur transmitter within the amateur band.

Q. 46. WHAT FREQUENCY SHOULD A CRYSTAL OSCILLATOR CIRCUIT BE TUNED TO FOR MAXIMUM STABILITY?

A. A crystal oscillator tuned circuit should be tuned to a slightly higher frequency than the exact crystal frequency.

As we vary the tuning capacitor on both sides of the exact crystal resonant frequency, we notice that on one side (the higher capacity side) the oscillator quickly stops oscillating, while on the other side (the lower capacity side), the oscillation gradually stops. Thus, if we set the tuning capacitor at the exact crystal frequency, we will get maximum oscillator output, but the slightest load change in the wrong direction will cause the oscillator to cease operating. If we reduce the capacity slightly, we will have less oscillator output, but slight changes in load conditions will not stop the oscillations.

Q. 47. WHAT ARE MICROWAVE FREQUENCIES? WHAT TYPE OF OSCILLATOR IS COMMONLY USED TO GENERATE MICROWAVES?

A. Microwave signals refer to frequencies above 300 MHz. Their wavelength is less than one meter. Magnetrons and klystrons are commonly used to generate microwaves.

Q. 48. HOW DOES THE POSITIONING OF A POWDERED IRON TUNING SLUG AFFECT THE FREQUENCY OF THE OSCILLATOR IT

IS TUNING?

A. The inductance of a coil depends, among other factors, on the permeability of the material within the field of the coil. The permeability of air is 1. The permeability of the typical iron core will be in the range of 20 to over 1000. When a core is inserted in a coil, the inductance will increase and therefore, the frequency of the oscillator will decrease. As the core is removed from the coil, the inductance decreases and the frequency of the oscillator increases. If the core is inserted part way into the coil, the inductance and frequency will be at an intermediate value. Many variable oscillators are tuned in this manner.

Q. 49. WHAT PRECAUTION(S) SHOULD BE TAKEN WHEN MEASURING THE RECTIFIED GRID VOLTAGE IN AN OSCILLATOR WITH A DC VOLTMETER?

A. A high resistance meter, such as a vacuum tube voltmeter, should be used to measure the grid voltage of an oscillator. If a low resistance meter is used, it will load down the grid circuit and give a wrong reading, or probably cause the oscillator to stop oscillating.

It is also important that the voltmeter be "RF isolated" from the oscillator. In other words, the capacity of the voltmeter or its cable must not be introduced into the oscillator to disturb the oscillator action. This is accomplished by having a resistor of one megohm or higher in the voltmeter probe tip.

In measuring the grid voltage of an oscillator, the negative terminal of the voltmeter must go to the grid.

INSTRUMENTS AND MEASUREMENTS

Q. 50. HOW DOES A CATHODE-RAY TUBE OPERATE? WHAT MAGNITUDE OF VOLTAGE IS NORMALLY USED TO BIAS THE PLATES OF A CATHODE-RAY TUBE? WHAT PURPOSE DOES THIS MAGNITUDE OF BIAS VOLTAGE SERVE?

A. Fig. 50 illustrates an elementary form of a cathode ray tube. The purpose of a cathode ray tube is to draw a graph, showing the waveforms of electrical signals. In a cathode ray tube, a fine beam of electrons is produced, focussed, deflected and accelerated to a screen. The beam can be deflected so that patterns can be formed on the screen.

The cathode ray tube contains a cathode which emits electrons. The

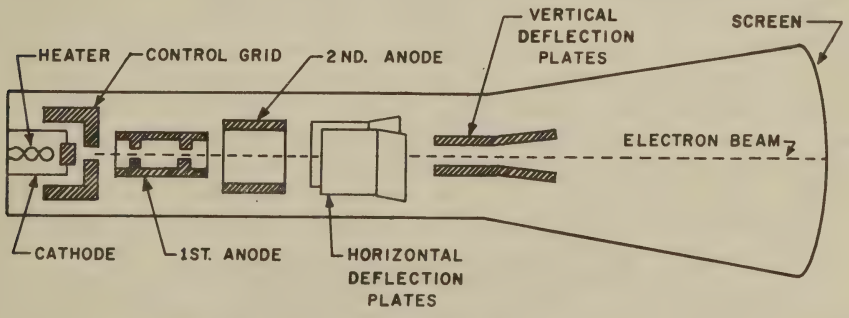

Fig. 50. A cathode ray tube.

electrons pass through a small opening in the control grid. The control grid acts the same as an ordinary tube's control grid in that it controls the amount of electrons in the beam. The electrons then pass through the first anode, which is positively charged, and which propels the electrons toward the screen. By varying the potential on the first anode, we are able to focus the electron stream so that a very fine beam reaches the screen. The second anode has a high positive voltage on it and further accelerates the electrons toward the screen. The electrons then pass between the vertical and horizontal deflection plates. By placing varying potentials on these plates, the electrons are attracted to the positively charged plates and repelled by the negatively charged plates, causing the beam to move vertically or horizontally in proportion to the charges on the plates. Some cathode ray tubes use magnetic coils instead of electrostatic plates to deflect the beam. Finally, the beam of electrons strikes a phosphor material on the screen which lights up and glows as long as the electrons are striking it. When the beam is deflected, light is generated wherever the beam strikes the screen. By applying various voltages to the deflection plates or coils, we get different patterns on the screen.

The second anode is generally connected to the deflection plates so that there is no great difference of potential in this area of the tube. Also, the voltage on the deflection plates can be varied by panel controls so that we can move the image on the screen up or down, or side to side. In this way, we can center the image, or move it to any part of the screen.

Q. 51. AN OSCILLOSCOPE IS USED TO STUDY THE RELATIONSHIP BETWEEN THE INPUT AND OUTPUT OF AN AMPLIFIER PRODUCED BY A VOICE SIGNAL. HOW WOULD THE SCOPE PATTERN DISPLAY A LINEAR RELATIONSHIP BETWEEN THE INPUT AND OUTPUT SIGNALS?

A. An oscilloscope can be used to determine the linearity of an audio amplifier in the following manner:

(1) Feed a pure sine wave audio signal into the amplifier under test.

(2) At the same time, feed the audio signal to the horizontal input of an oscilloscope. The oscilloscope must have identical vertical and horizontal deflection amplifiers to insure that the phase shift will be identical. The deflection amplifiers must have low distortion and flat response to about ten times the highest frequency that will be used.

(3) Feed the output of the amplifier to the vertical input of the oscilloscope.

Fig. 51A. Fig. 51B. Fig. 51C. Fig. 51D.

Fig. 51. Oscilloscope patterns.

(4) If the amplifier under test is perfectly linear and introduces no distortion or phase shift, and the gain of the oscilloscope is adjusted to produce equal deflection amplitude from the input and output signals, the oscilloscope will display the pattern shown in Fig. 51A, a straight line at 45°. If distortion is present, the line will not be straight - it will curve at the ends. See Fig. 51B. If there is phase shift but no amplitude or harmonic distortion present, an ellipse will be formed, as in Fig. 51C. Fig. 51D shows a 90° phase shift with no other distortion present.

Q. 52. WHAT MEANS MAY BE EMPLOYED TO MEASURE LOW FREQUENCIES? HIGH FREQUENCIES? VHF AND UHF?

A. Frequency measurements are usually made by comparing the unknown frequency with a harmonic and/or subharmonic from an accurate crystal controlled oscillator. The oscillator is normally checked and adjusted to agree with standard frequency radio stations such as WWV, WWVH, WWLV, WWVB, LOL, VNG, MSF, JJY, ZUO and others.

The crystal frequency is then multiplied and divided to provide a large number of reference points throughout the spectrum. Increments between these signals are measured by using a variable oscillator with very precise calibrations and provision for exact correction to bring it into agreement with the basic crystal controlled standard. This oscillator signal and the unknown frequency signal are combined in a heterodyne detector and the variable oscillator adjusted to zero beat with the unknown. Then the frequency is read on the dial directly, (or the dial reading is added to the nearest known harmonic of the standard frequency, depending on the circuit arrangement used). The variable oscillator and heterodyne detector, with its audio amplifier and beat indicator meter or oscilloscope, is called a heterodyne frequency meter.

The system above can be used from audio frequencies to over 1000 Mc. However, it is slow, clumsy and requires considerable operator skill.

The modern method is to use a direct digital readout electronic frequency counter. A counter has the same crystal controlled standard frequency oscillator, multipliers and dividers as in the older method. In the frequency counter circuits, an electronic "gate" is opened and the unknown signal is fed into the counting circuits. Here, each cycle is counted until the timing circuit closes the gate and stops the signal from going into the counting circuits. The total count made during the time the gate was open is then displayed on the front of the instrument in numerals. The reading can be held indefinitely or automatically recycled to take a new measurement every few seconds, as desired. This method is extremely simple to use and requires very little operator skill to make precise frequency measurements. Counters can be used from a few cycles to well over 10,000 Mc. Some other devices used for less precise frequency measurements are wavemeters, receivers, lecher wires and frequency meters (both magnetic and electronic).

RECEIVERS AND INTERFERENCE

Q. 53. OF WHAT IMPORTANCE IS THE SIGNAL-TO-NOISE RATIO OF A RECEIVER? AT WHAT RADIO FREQUENCIES IS THIS RATIO

MOST IMPORTANT?

A. The signal-to-noise ratio of a receiver is the factor that limits the minimum signal level at which useful information can be obtained from the signal.

As the frequency increases, the atmospheric noise level decreases. Therefore, the higher the frequency, the more useful a good signal to noise ratio becomes.

Q. 54. WHERE IN A RECEIVER CIRCUIT SHOULD A LIMITER/BLANKER STAGE BE PLACED TO PROVIDE MAXIMUM UTILITY?

A. A noise limiter/blanker stage should be placed as close as possible to the antenna. It is important to eliminate the noise pulses before the signal reaches the various selective tuned circuits. The selective tuned circuits tend to stretch the noise pulses. It is difficult to remove wide noise pulses without distorting the signal.

Q. 55. HOW DO TRIMMER AND PADDER CAPACITORS AFFECT THE LOW AND HIGH FREQUENCIES IN RECEIVER TUNING?

A. Trimmer and padder capacitors are used to adjust the tuned circuits in a receiver to obtain accurate dial calibrations and get the tunable circuits to track together with the correct frequency relations.

In a typical receiver, the antenna and RF coils are tuned to the frequency indicated on the dial. The oscillator must track with these circuits at the dial frequency plus (or minus) the intermediate frequency.

Trimmers are also used to adjust the intermediate frequency amplifier tuned circuits for best gain and selectivity.

Q. 56. DEFINE THE CONVERSION EFFICIENCY OF A MIXER TUBE.

A. The converter efficiency (or conversion gain, as it is commonly called) of a mixer tube is the ratio of the IF voltage developed in the output of the mixer to the RF input voltage at the grid of the mixer. In other words, the converter efficiency tells us what the amplification of the mixer is with respect to the IF signal.

The amplification of the mixer stage is about one-half of what it would be if the same tube were used as a straight through IF amplifier.

Q. 57. HOW WILL A LONG AND A SHORT TIME CONSTANT AUTOMATIC VOLUME CONTROL CIRCUIT AFFECT SIGNAL RECEPTION?

A. An RC filter is employed between the detector and the stages receiving the AVC signal. The purpose of the filter is to prevent the audio variations from getting back to the RF and IF stages that receive the AVC signal. If the time constant of this filter is too low (less than 0.04 second), the audio variations would get back to the RF and IF stages and partially cancel the modulation on an AM signal. This will reduce its readability and cause distortion. If the time constant is too long (more than 0.2 second), the receiver will not be able to counteract rapid fading and other changes in signal level that the AVC is supposed to suppress.

In SSB and CW reception, a long time constant is necessary in order to hold the gain fairly constant, even with the intermittent character of the signals.

Q. 58. HOW DO PHASING CAPACITORS HELP STABILIZE CRYSTAL FILTER CIRCUITS?

A. In a crystal filter, the crystal, two capacitors (or a center-tapped coil) and the phasing capacitor are connected in a bridge circuit to permit the phasing capacitor to be adjusted, to balance out the capacity across the crystal holder. When this is accurately done, the only path for the signal is through the crystal, which operates as a very high Q series tuned resonant circuit. This provides the maximum selectivity that the circuit can produce.

Q. 59. HOW DO RECEIVERS FOR REMOTE CONTROL OF OBJECTS AND REGULAR TYPE COMMUNICATIONS RECEIVERS DIFFER IN BASIC OPERATION?

A. Receivers for general communications and remote control differ as follows:

	COMMUNICATION	REMOTE CONTROL
Size and weight	Large	Small
Frequency coverage	Tunable over a wide range	Fixed frequency
Power comsumption	Moderate to high	Low
Output	Audio, to speaker	Tone or pulse to electro-mechanical control unit

Q. 60. IF A CRYSTAL LATTICE BANDPASS FILTER HAS BANDWIDTHS OF 3 KC/S AT THE 60 DB POINTS AND 1.5 KC/S AT THE 6 DB POINTS, CALCULATE THE SHAPE FACTOR.

A. The shape factor is equal to 2. The shape factor is generally equal to the ratio of the bandwidth at 60 db to the bandwidth at 6 db.

$$\frac{3 \text{ kc.}}{1.5 \text{ kc.}} = 2.$$

Note that we use the term "generally" in the above statement. This is because some filters may be designated at other points, such as 4 db and 40 db or 3 db and 50 db.

Q. 61. HOW DOES A SQUELCH CIRCUIT OPERATE? DRAW A COMMONLY USED SQUELCH CIRCUIT.

A. The purpose of the squelch circuit is to silence the receiver when no signal is being received. With no signal being received, there is a hash or hiss noise that is offensive to most listeners. Fig. 61 illustrates a simplified schematic of a differential squelch circuit. It operates as follows:

The output of the discriminator is fed to points A and C. The negative limiter bias is fed to point B. With no signal, the noise will appear at point A and be amplified by V1, the noise amplifier. The network, C1 and R1, favors the noise and rejects the signal. The amplified noise then goes to the noise diode, where it is rectified. The rectified DC resulting from the noise appears as a positive voltage on the grid of the squelch gate tube V2. This causes heavy plate current to flow through V2 and R3. Since R3 is the cathode bias resistor for V3, the heavy current will cause a large bias voltage across R3, which will cut off V3.

Since V3 is the first audio amplifier, nothing will get through to the speaker. Thus we see how the receiver is squelched when no signal is received.

When a signal is received, the limiter operates to cut down the noise and the amount of noise appearing at V1 is almost zero. In addition to this, the incoming signal creates a strong negative limiter bias, which appears at point B. This appears at the grid of V1 and cuts V1 off. Thus, the output of V1 is zero and consequently, the voltage appearing

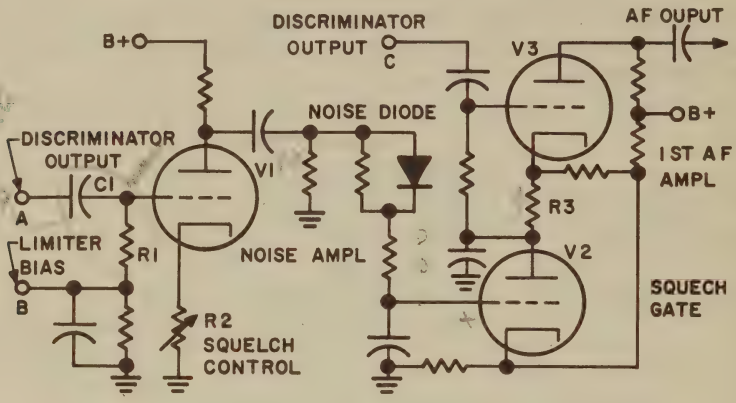

Fig. 61. A differential squelch circuit.

at the grid of V2 from the noise amplifier and diode is at a minimum. Under these conditions, the cathode bias at V2 is such that V2 is almost cut off. The large bias voltage at V3 disappears and V3 operates normally. Thus we see how the receiver operates normally when a signal is received.

Q. 62. HOW DOES AMATEUR TVI USUALLY AFFECT TELEVISION RECEPTION?

A. The amount of Television Interference (TVI) caused by an amateur transmitter depends on many factors. Some of them are: the distance between the amateur antenna and the TV antenna; the TV signal strength; the distance between the TV transmitter and the TV receiver; the selectivity characteristics of the TV receiver; the quality and gain of the TV receiver's antenna system; the spurious and harmonic output of the amateur transmitter; the frequency and type of emission being used by the amateur; the channel being used by the TV receiver, etc.

If the interference is moderate to strong, a series of dark horizontal bars will be present on the screen and their intensity and movement will vary in accordance with the audio modulation at the ham transmitter. If the interference is very strong, the entire TV picture will almost disappear. If the interference is slight, "cross-hatching" or diagonal lines will appear on the screen.

Q. 63. WHAT IS THE IMAGE-RESPONSE OF A RECEIVER? HOW CAN IT BE REDUCED?

A. An image is an UNWANTED signal that differs in frequency from the local oscillator frequency by an amount equal to the intermediate frequency. For instance, if we are tuned to 1000 kc. and the IF is 456 kc., then the oscillator frequency would be 1456 kc. Assume there was a station at 1912 kc. The signal of this station would appear at the grid of the converter and beat with the oscillator to produce the IF of 456 kc. This signal would be heard, in addition to the 1000 kc. signal that we are tuned to. We call 1912 kc. the image frequency. By adding a tuned RF amplifier ahead of the mixer, we reduce the reception of images. This is because the RF amplifier is tuned to the frequency of the station that we wish to receive and the image frequency is attenuated by the additional tuned circuits. Without the RF amplifier, the image frequency has only to get through the mixer tuned circuit.

We can also reduce image interference by using a higher Intermediate Frequency. This will place the image frequency further away from the desired frequency, thereby permitting the RF amplifier tuned circuits to attenuate the image frequency signal more effectively.

In general, the tuned circuits ahead of the mixer should be as selective as possible to reduce images and other interfering signals.

Q. 64. WHAT ARE SOME DIFFERENT TYPES OF NOISE VOLTAGES ENCOUNTERED IN AMATEUR RECEIVERS? HOW IS EACH TYPE GENERATED?

A. Noise voltages affecting reception can be classified into two categories: internal and external.

Internal noise can be generated in the RF amplifier tube or transistor, as well as tubes in the mixer, IF amplifier or audio amplifier. It can also be generated in components, such as resistors. Some of the means by which internal noise is generated are:

(1) Shot effect -- noise generated by the fact that electrons in a tube do not flow in a steady smooth stream, but tend to strike the plate in bunches at random frequencies.

(2) Thermal agitation -- random movement of electrons in a tube or part produces small voltages which, when amplified, result in noise at the loudspeaker.

(3) Microphonics -- mechanical vibrations cause a movement of the tube's elements which generate random voltages, resulting in noise.

(4) Hum pickup -- the hum due to insufficient power supply filtering or pickup by sensitive circuits are amplified and heard in the speaker.

External noise, commonly called static, is caused by man-made devices and by natural sources. Noise is generated in man-made devices when electrical contacts are opened and closed. This occurs in lighting, power circuits, automobile ignition, corona discharge, motor commutators, etc. Noise from natural sources come from lightning, rain and snow static and radiation from the sun and space. Aside from radiation, this type of noise is generated by the electrical arc that occurs in lightning and static.

Q. 65. HOW SHOULD A WAVE TRAP BE CONNECTED TO A RECEIVING ANTENNA CIRCUIT TO ATTENUATE AN INTERFERING SIGNAL?

A. Fig. 65 illustrates two methods of using wave traps to attenuate an interfering signal. The traps are resonant to the frequency of the interfering signal. Fig. 65A shows a series-tuned wave trap in shunt with the input to the receiver. Because the trap is series resonant, it offers the interfering signal a low impedance path to ground. The interfering signal is, therefore, shunted to ground and it does not get into the receiver.

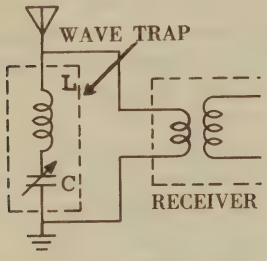

Fig. 65A.

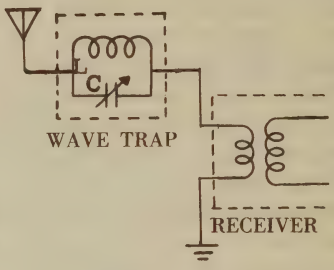

Fig. 65B.

In Fig. 65B, the parallel resonant trap offers a high impedance to the interfering signal and therefore, attenuates it while passing other signals to the receiver with little or no loss.

Q. 66. HOW CAN UNWANTED VHF RESONANCES IN A TRANSMITTER AMPLIFIER BE MOVED FROM TV CHANNEL FREQUENCIES?

A. Unwanted VHF resonances in a transmitter amplifier can be moved from TV channel frequencies by changing lead lengths, bypass capacitor sizes, or adding inductances (parasitic suppressor chokes) in the offending circuits.

Q. 67. WHAT MAJOR FACTORS AFFECT THE Q OF A COIL? OF A CIRCUIT? FOR WHAT PURPOSE IS A Q-MULTIPLIER USED IN AMATEUR EQUIPMENT?

A. The Q of a coil is a measure of its gain or "quality". It is equal to the inductive reactance, divided by the resistance of the coil. The Q is affected by the length, diameter, spacing and type of wire used. It is also affected by the length, diameter and type of coil form used. It is also affected by its proximity to the chassis and other metal parts. The Q of a circuit is close in value to the Q of the coil and is affected by the same factors.

A Q-multiplier consists of a regenerative stage of amplification. Its purpose is to increase the gain and selectivity of the receiver.

Q. 68. HOW DOES A FREQUENCY CONVERTER OPERATE?

A. Frequency conversion is a process whereby a signal is changed or converted to another frequency. All superheterodynes use frequency converters. The incoming signal is fed to a converter tube, along with another signal that is generated by a local oscillator. The two signals are mixed together in the converter tube and two new frequencies are produced. They are the sum and difference of the two original frequen-

cies. The output of the converter tube is tuned to the "difference" frequency (Intermediate Frequency), which is then amplified and passed on to the next stage.

FREQUENCY MODULATION AND FREQUENCY SHIFT KEYING

Q. 69. DEFINE THE DEVIATION RATIO IN A FREQUENCY MODULATED SIGNAL.

A. The deviation ratio of an FM system is the maximum frequency deviation, divided by the highest audio frequency that is modulating the carrier. An example will illustrate this. Let us assume that we have an 80 Mc. carrier that is modulated by audio whose highest frequency is 5 kc. Let us further assume that the maximum frequency deviation of the carrier is ± 40 kc. The deviation ratio would then be: $\frac{40 \text{ kc}}{5 \text{ kc}}$ or 8.

Q. 70. HOW ARE REACTANCE TUBES USED?

A. Fig. 70 illustrates a frequency modulated oscillator using a reactance tube modulator. V2 is the oscillator tube and V1 is the modulator tube. The modulator tube is across the tuned circuit of the oscillator. The circuit of the modulator is such that the plate current lags

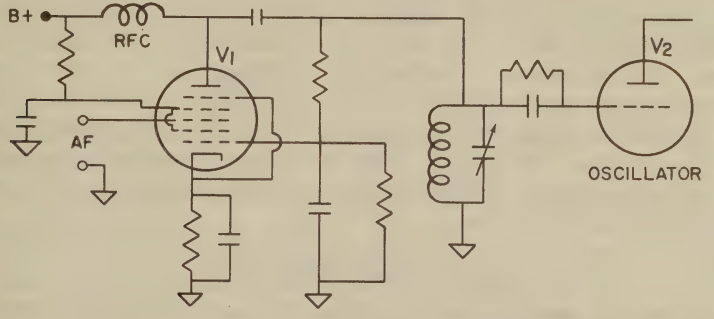

Fig. 70. A reactance tube modulator.

the plate voltage. This means that the reactance tube acts as an inductor across the oscillator's tank circuit. Audio is fed to the grid of the modulator tube and causes its plate current to vary accordingly. These audio variations cause the "acting" inductance to vary and this, in turn, causes the oscillator's frequency to vary. Thus, frequency modulation is produced. In Fig. 70, the reactance tube acts as an inductance. In some circuits, the reactance tube can act as a capacitance.

Q. 71. WHAT TYPE OF SIGNAL WILL BE PRODUCED WHEN THE OUTPUT OF A REACTANCE MODULATOR IS COUPLED TO A HARTLEY OSCILLATOR AND MULTIPLIED IN FREQUENCY?

A. A reactance modulator coupled to a Hartley oscillator will produce Frequency Modulation. The reactance modulator acts as an inductance or capacitance across the oscillator's tuned circuit and variations in the modulator cause the frequency of the oscillator to vary. For purposes of stability, the oscillator's frequency is low. Frequency multipliers can then multiply the frequency to the desired output frequency.

Q. 72. HOW MAY A LIMITER BE EMPLOYED IN AN FM RECEIVER?

A. A limiter is used in an FM receiver to clip or cut off the amplitude variations in the FM signal. The amplitude variations represent interference or noise and are removed by the limiter stage before the signal gets into the FM detector. The limiter stage is between the last IF stage and the FM detector stage.

In addition to using a sharp cutoff tube, the limiter stage is operated with low plate and screen voltages. It also uses grid leak bias which responds quickly to amplitude variations and counteracts them.

Q. 73. WHAT IS MEANT BY FREQUENCY SHIFT KEYING AND HOW IS IT ACCOMPLISHED?

A. Frequency shift keying (FSK) is a means of keying a transmitter by varying its frequency. The amplitude of the carrier is kept constant and when the key is depressed, the output frequency is shifted or changed by approximately 900 cycles or less. Thus, the dots and dashes will come out at one frequency and the spaces will come out at another frequency.

There are several ways by which FSK can be accomplished. One way is to key a capacitor or inductor in or out of a tuned circuit by a relay or switching diode. The resonant frequency of the circuit is shifted each time the capacitor or inductor is "keyed" in. Another way is to have a reactance tube across a tuned circuit in a manner similar to producing FM. Each time we depress the key, we cause the impedance of the tube to change. Since the tube acts as a reactance across a tuned circuit, a change in the tube's impedance will change the resonant frequency of the tuned circuit.

TELEVISION AND RTTY

Q. 74. WHY ARE SYNCHRONIZING PULSES TRANSMITTED WITH TELEVISION SIGNALS?

A. The synchronizing pulses are used to synchronize the electron beam movement in the cathode ray tube in the television receiver with that in the transmitter. In other words, when the beam in the transmitter is sending out the first line of picture information, we must make sure that the beam in the television receiver is moving across the first line; when the transmitter beam is moving from the bottom of the picture up to the top to start a new picture, the receiving tube's beam must be doing the same thing, etc.

Q. 75. DRAW A BLOCK DIAGRAM OF AN RTTY SYSTEM SHOWING THE PRIMARY FUNCTION OF EACH STAGE. WHAT IS THE PROPER WAY OF IDENTIFYING AN RTTY TRANSMISSION? WHAT IS THE MOST WIDELY USED FREQUENCY DIFFERENCE BETWEEN THE MARK AND SPACE FREQUENCIES IN A CONVENTIONAL RTTY TRANSMITTER?

A. Fig. 75 shows a block diagram of an RTTY (radioteletype) system. RTTY uses a special typewriter and converter instead of a telegraph key.

RADIOTELETYPE SYSTEM

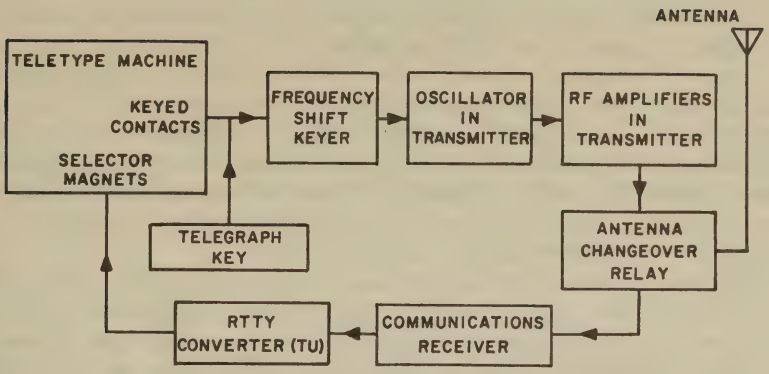

Figure 75.

Identification of an RTTY transmission should be made on RTTY and also by sending the call sign of the transmitting station in Morse Code (CW) or by telephony.

The most widely used frequency difference between the mark and space frequencies in a conventional RTTY transmitter is 850 cycles.

SINGLE SIDEBAND

Q. 76. HOW CAN YOU DISTINGUISH BETWEEN A PRODUCT AND AN ENVELOPE DETECTOR?

A. The envelope detector is the common detector that is used to detect amplitude modulated signals. The envelope of an amplitude modulated signal represents the audio that originally modulated the RF carrier. An envelope detector removes the bottom half of the modulated signal, along with all of the RF, and reproduces half of the envelope or audio. The simplest and usual form of envelope detector uses a diode tube or semi-conductor. It is called a diode detector. Two other less used envelope detectors are the grid leak and plate detectors. They use triode tubes.

A product detector is a mixer that produces a signal resulting from the product of two different signals. One of these is the incoming signal and the other is the signal generated by a local oscillator. Product detectors are used to detect CW and suppressed carrier single sideband signals. The local oscillator provides a signal that beats with the CW signal to produce an audible signal. In single sideband detection, the local oscillator provides the carrier that is missing from the single sideband signal. The product detector is recognized by the oscillator which is not present in the envelope detector. The product detector usually uses a triode, a multigrid tube or a transistor. Additional tubes that are often found with product detectors are coupling or isolating devices. Only one tube or section is the actual detector.

Q. 77. HOW WOULD THE RECEPTION OF A SINGLE SIDEBAND SIGNAL BE AFFECTED IF THE CARRIER IS NOT COMPLETELY SUPPRESSED? HOW CAN SPURIOUS SIGNALS IN THE OUTPUT OF THE

MIXER STAGE OF AN SSB TRANSMITTER BE SUPPRESSED?

A. When the carrier is not completely suppressed in a single sideband signal, a pure tone will be produced when the signal is tuned in, regardless of whether there is voice communication present or not. This is the same as one would expect when listening to a CW signal. If the signal is tuned in exactly and a good single sideband receiver is used, reception will be perfectly normal. If the receiver is slightly detuned, the beat frequency will be heard. When an ordinary receiver is tuned to such a signal, the tuning must be extremely exact in order to reduce the distortion produced by the beat frequency.

The existence of a non-suppressed carrier will also cause interference to a receiver tuned to a nearby frequency if the carrier is within the passband of that receiver. The normal "monkey chatter" of an off-tune single sideband signal is relatively inoffensive as compared with the steady tone beat of a carrier that is not completely suppressed.

Spurious signals in the output of the mixer stage of an SSB transmitter are suppressed by the use of a sufficient number of tuned circuits and/or filter circuits. Traps and neutralizing-type circuits can also be used to suppress the unwanted signals.

Q. 78. HOW CAN A RECEIVER BE ADJUSTED FOR SSB RECEPTION WHEN THE RECEIVER DOES NOT HAVE A PRODUCT DETECTOR?

A. A receiver that does not have a product detector can be used to receive an SSB signal. This is done by tuning the signal in carefully with the Beat Frequency Oscillator (BFO) off and the selectivity set as close to the 2 to 3 kc. bandwidth as possible. With the audio gain control near maximum and the AGC off, adjust the RF gain control for moderate volume. Turn the BFO on and tune it until the voice is most natural. If the signal strength changes, the RF gain control will have to be readjusted. To tune another SSB signal, use only the tuning and RF gain controls; do not touch the BFO control.

When a product detector is added to an older receiver that does not have one, we use the above tuning procedure. The only advantage is in the lower distortion produced by the product detector.

Q. 79. HOW DOES THE BEAT FREQUENCY OSCILLATOR AFFECT THE TUNING OF A SINGLE SIDEBAND SIGNAL?

A. A single sideband signal is usually understood to mean a single sideband, suppressed carrier signal. It is one in which the carrier has been suppressed. In order to make the signal, which consists only of the one sideband and no carrier, readable, it is necessary to re-insert the carrier. The beat oscillator in a receiver is the source of this carrier. When it is mixed with the signal in the product detector of the receiver, an amplitude modulated signal with one sideband is produced. It is then detected and the audio frequency signal is recovered. To obtain best results, the beat oscillator must be exactly on the same frequency as the carrier. In ordinary voice communication circuits, it can be off by about ±50 cycles with little effect on the readability. It will, however, disturb the naturalness of the voice.

Q. 80. DESCRIBE BRIEFLY THE BASIC SECTIONS OF A SINGLE

SIDEBAND (SSB) TRANSMITTER. IN WHAT SECTION OF A PROPERLY OPERATING SSB TRANSMITTING SYSTEM IS DISTORTION MOST LIKELY TO ORIGINATE? IN WHAT SECTION IS NON-LINEARITY MOST LIKELY TO ORIGINATE?

A. The two most common single sideband types of transmitters are the filter type and the phasing type. We will discuss the filter type. Fig. 80 shows a filter type SSB transmitter. The frequency components at the output of each circuit are indicated to the right of each block by a sketch.

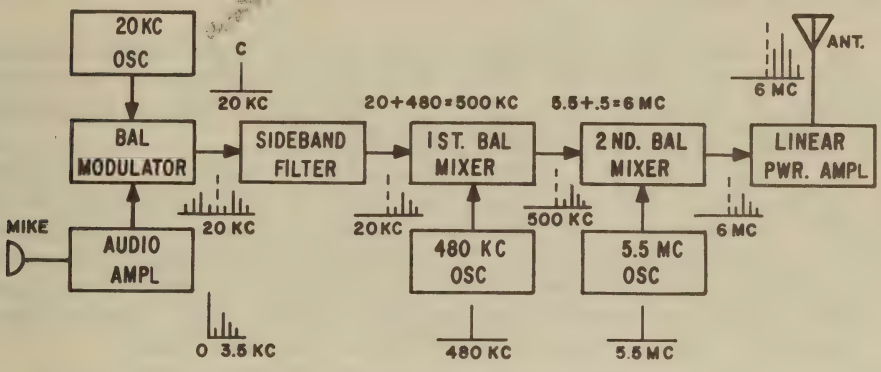

Fig. 80. A filter type SSB transmitter.

The 20 kc oscillator generates a single frequency reference signal. This signal combines with the audio output from the audio amplifier in the balanced modulator. The balanced modulator generates a double-sideband suppressed carrier signal with a center frequency of 20 kc. This means that the audio signal is distributed symmetrically above and below 20 kc. However, the 20 kc carrier is suppressed.

The double-sideband signal enters the sideband filter and emerges as a single-sideband (SSB) signal. The filter has removed the lower sideband.

The 20 kc. SSB signal is applied to a cascade of two balanced mixers. The first balanced mixer heterodynes the 20 kc. SSB signal to 500 kc. The 480 kc. oscillator provides the signal required to perform this heterodyning process. The second balanced mixer and the 5.5 Mc. oscillator repeat the heterodyning process, raising the signal frequency to the required 6 Mc. The reason two mixers are employed is to insure adequate image rejection of the 20 kc. signal frequency.

The linear power amplifier (usually Class B) amplifies the 6 Mc. SSB signal to the proper power level required. The amplifier is linear in order to preserve the audio which is already impressed on the carrier.

Distortion (including non-linearity) is most likely to originate in the highest level amplifier stage (the final amplifier). This is because we try to get the maximum amount of power out of the final amplifier, and generally operate it as close as possible to its maximum ratings.

Q. 81. WHAT EFFECT WILL EXTENDING THE LOW-FREQUENCY AUDIO RESPONSE OF A SIGNAL HAVE ON THE DESIGN OF AN SSB RECEIVER?

A. When the low frequency response of a signal is extended in an SSB receiver, the IF filter should be designed to have a steeper slope on the carrier side in order to maintain the normal attenuation at the carrier frequency. It must do this while having little or no attenuation at the lowest desired frequency. In actual use, the tuning would have to be more accurate than with the usual receiver.

If we extend the low frequency response, there would be no improvement in the readability of a voice signal. The voice, however, would sound more natural.

Q. 82. HOW CAN THE TWO-TONE TEST OUTPUT OF A LINEAR AMPLIFIER BE USED TO TELL IF A TRANSMITTER IS WORKING PROPERLY? SHOW SCOPE PATTERNS FOR OPTIMUM, OVERDRIVEN AND UNDERDRIVEN AMPLIFIER CONDITIONS.

A. The two-tone test output from a linear amplifier can be fed into an oscilloscope and the waveform produced will permit analysis of the amplifier performance. Typical waveforms and the conditions they indicate are in many publications. Fig. 82A shows the normal oscilloscope pattern using a two-tone test. Fig. 82B and Fig. 82C indicate improper amplifier operation. Note the flattened peaks in Fig. 82B. This is caused by overdrive. Fig. 82C shows the result of excessive bias.

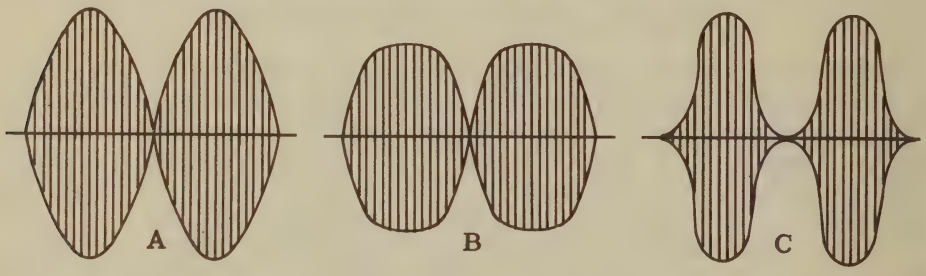

Fig. 82. Oscilloscope patterns using a two-tone test.

A spectrum analyzer is the ideal device for analysis of a two-tone test signal. A receiver with a very narrow IF bandwidth and dial calibrations of one kc. or less can be used as a substitute for a spectrum analyzer with fair results.

Q. 83. WHAT USEFUL FUNCTIONS DOES A BALANCED MODULATOR PERFORM IN A RADIO TRANSMITTER?

A. A balanced modulator is used in a transmitter to mix the audio frequency signal with the carrier and at the same time, suppress the carrier to a very low level. The output of such a balanced modulator is double sideband, suppressed carrier. A filter can then be used to reject one sideband when a single sideband signal is desired.

TRANSISTORS

Q. 84. HOW DO NPN TYPE TRANSISTORS DIFFER FROM THE PNP TYPE? HOW DOES THEIR BIAS DIFFER?

A. An NPN type transistor is one that contains two sections of N

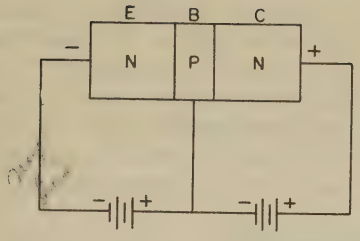

Fig. 84A.

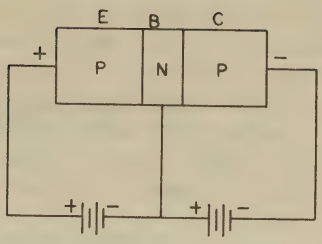

Fig. 84B.

Fig. 84. NPN and PNP transistors.

type material "sandwiching" a section of P type material. A PNP transistor is one that contains two sections of P type material "sandwiching" a section of N type material. See Figs. 84A and 84B. N type material contains an abundance of electrons, whereas P type material contains an abundance of positively charged particles known as "holes".

The bias polarity for an NPN transistor is opposite to that of a PNP transistor. This is shown in Figs. 84A and 84B. E, B and C stand for Emitter, Base and Collector, respectively.

Q. 85. WHAT IS THE PHASE RELATION BETWEEN THE INPUT AND OUTPUT SIGNALS IN THE COMMON-EMITTER, COMMON-BASE AND COMMON-COLLECTOR CIRCUITS?

A. The phase of the output is the same as the input in common base and common collector amplifiers. It is 180° out of phase in common emitter amplifiers.

Q. 86. DEFINE THE ALPHA CUT-OFF FREQUENCY OF A TRANSISTOR. HOW IS THIS PARAMETER OF USE IN CIRCUIT DESIGN?

A. The alpha cutoff frequency of a transistor is defined as the frequency at which the current gain of a common base arrangement decreases to .707 of its 1 kc. value. In the case of some large, low frequency power transistors, 270 cycles is used instead of 1 kc.

Alpha cutoff frequency is used to calculate the high frequency performance of a transistor in an amplifier or oscillator circuit.

Q. 87. HOW ARE THE EMITTER, BASE AND COLLECTOR OF A TRANSISTOR BIASED FOR AMPLIFIER OPERATION? HOW ARE THEY BIASED FOR CUTOFF (OPEN CIRCUIT) AND SATURATION (SHORT CIRCUIT)?

A. For operation as amplifiers, transistors must have bias applied to the base in the same polarity as the collector. Base current must be made to flow in order to have a current flow in the collector circuit.

To cut off the collector current, it is necessary to reduce the bias between the base and the emitter to zero. To obtain saturation, the bias must be increased to the point where there is very little increase in collector current when the base bias is increased.

For Class A operation, the bias is adjusted to a point in the linear portion of the base current-collector current curve. For Class B oper-

ation, the bias is adjusted for a small amount of collector current to flow. The exact point is determined by the elimination of crossover distortion in the waveform. The conduction angle is at least 180°. Class C operation uses bias beyond cutoff. This can be either zero or reverse bias on the base. In Class C operation, the conduction angle is appreciably less than 180°. Bias current for the base is obtained from either a divider or a dropping resistor from the collector power supply.

RULES AND REGULATIONS

Q. 88. WHAT ARE A5 AND F5 EMISSIONS? ON WHAT AMATEUR FREQUENCIES CAN THESE EMISSIONS BE TRANSMITTED? CAN A5 EMISSION BE TRANSMITTED SATISFACTORILY USING ONE SIDEBAND ONLY?

A. A5 emission refers to the emission of amplitude modulated television signals. F5 refers to the emission of FM television signals. A5 and F5 emissions are permitted on amateur bands above 420 MHz. "Narrow-band" television ("slow-scan") is permitted on parts of all bands below 420 MHz, with the exception of the 1.8-2.0 MHz band.

A5 emission can be transmitted satisfactorily, using one sideband only.

Q. 89. WHAT IS A THIRD PARTY AGREEMENT? WHAT COUNTRIES HAVE AGREEMENTS WITH THE UNITED STATES?

A. A third party agreement is an agreement between two countries allowing their respective radio amateurs to handle messages on behalf of a third party. Most countries forbid their amateurs to handle messages on behalf of other persons. However, the following countries have entered into third party agreements with the United States:

Bolivia	Columbia	Ecuador	Israel	Panama
Brazil	Costa Rica	El Salvador	Liberia	Paraguay
Canada	Cuba	Haiti	Mexico	Peru
Chile	Dominican Republic	Honduras	Nicaragua	Uruguay
				Venezuela

The third party agreements with these countries stipulate that the messages handled must be of a character that would not normally be sent by any other existing means of telecommunications.

90. All amateurs should be familiar with Part 97 of the Federal Communication Commission's Rules and Regulations governing the Amateur Radio Service. These Rules and Regulations may be obtained from the United States Government Printing Office, or from the various Amateur Radio publications, including the AMECO Amateur Radio Theory Course.

Q. 91. WHAT ARE SOME OF THE FACTORS THAT AFFECT THE FIELD STRENGTH OF A SIGNAL RADIATED FROM AN ANTENNA?

A. The following are the major factors that affect the field strength of a signal radiated from an antenna: Type of antenna, height of antenna, power delivered to antenna, type of ground and terrain near antenna.

FCC-TYPE EXAMINATION

1. If a 200 cycle signal modulates a 2,000 kc. carrier, which of the following frequencies will not be a component in the resultant signal:
   a. 2,000.2 kc.
   b. 0.2 kc.
   c. 1,999,800 cycles
   d. 2.2 kc.

2. The percentage of power in the upper sideband in an AM system is:
   a. 16.7 b. 33.33 c. 50 d. 66.67

3. Which of the following is not used in a limiter stage?
   a. low plate voltage
   b. low screen voltage
   c. cathode bias
   d. sharp cutoff tube

4. A high resistance meter is used to measure the grid voltage of an RF oscillator because:
   a. it has a high resistance in the probe tip
   b. it reduces the capacitance of the grid circuit
   c. it loads the circuit very lightly
   d. a high resistance voltmeter should not be used to measure the grid voltage of an RF oscillator

5. In frequency shift keying:
   a. the dots appear at a high frequency and the dashes at a lower frequency
   b. the dots appear at a low frequency and the dashes at a higher frequency
   c. the dots and dashes appear at one frequency and the spaces appear at another frequency
   d. the dots, dashes and spaces all appear at different frequencies

6. What is the inductive reactance of a 20 millihenry choke at 3 kc.?
   a. 60 ohms
   b. 377 ohms
   c. 188 ohms
   d. 37,700 ohms

7. In a circuit containing some resistance and some capacitance:
   a. the current and voltage are in phase
   b. the current lags behind the voltage
   c. the current leads the voltage by 90°
   d. the voltage lags behind the current

8. Multiplying the resistance by the capacitance gives us the:
   a. power factor
   b. time constant
   c. conductance
   d. leakage factor

9. An excellent dielectric for high frequency bypass capacitors is:
   a. mica b. bakelite c. glass d. paper

10. F5 emission refers to:
   a. facsimile
   b. pulse emissions
   c. FM television
   d. FM telephony

11. The alpha cutoff frequency of a transistor is defined as the frequency at which the:
   a. power gain decreases to .707 of its 1 kc. value
   b. current gain decreases to .707 of its 1 kc. value
   c. voltage gain decreases to .707 of its 1 kc. value
   d. amplification factor decreases to .636 of its 1 kc. value

12. The phase relationship between the input and output circuits in a transistor common emitter amplifier is:
   a. 180° out of phase
   b. in phase
   c. 45° out of phase
   d. 90° out of phase

13. In a properly operating single sideband transmitting system, distortion can most likely originate in the:
   a. audio stages
   b. oscillator stage
   c. modulator
   d. final amplifier

14. The purpose of a beat oscillator in a single sideband receiver is to:
   a. remove one of the sidebands
   b. replace one of the sidebands
   c. remove the carrier
   d. re-insert the carrier

15. A product detector is used in a:
   a. single sideband receiver
   b. radio teletype receiver
   c. remote control receiver
   d. frequency modulation receiver

16. A single sideband signal, whose carrier is not completely suppressed, can cause:
   a. frequency modulation of the carrier
   b. steady tone beats
   c. parasitic oscillation
   d. failure of the AGC system

17. In order to synchronize the transmission of information at the studio with the CRT action in the television receiver, the TV signal contains:
   a. low frequency tones
   b. integrating and differentiating signals
   c. CW signals
   d. pulses

18. A Class A amplifier:
   a. has medium efficiency
   b. is biased at or near cutoff
   c. requires low grid drive
   d. has high efficiency

19. A Class C amplifier:
    a. is biased at several times cutoff
    b. has low efficiency
    c. requires low drive
    d. has excellent fidelity

20. A Class B amplifier:
    a. is biased at the center of the IpEg curve
    b. has excellent fidelity
    c. has its plate current flowing for approximately one-third of the cycle
    d. has medium efficiency

21. Harmonic emissions are attenuated by:
    a. a low pass filter at the transmitter
    b. a high pass filter at the transmitter
    c. a band-stop filter at the transmitter
    d. a crystal lattice filter at the transmitter

22. Which of the following causes grid current to flow in a Class A amplifier?
    a. low signal voltage drive
    b. low bias
    c. high bias
    d. low plate voltage

23. Which of the following is used to express a ratio between two power levels in an audio system?
    a. volume unit
    b. H-pad
    c. watt
    d. decibel

24. Excessive production of harmonics cannot be eliminated by:
    a. a Faraday shield
    b. capacitive coupling
    c. a low pass filter
    d. a high Q plate tank circuit

25. In a grounded grid amplifier:
    a. neutralization is not required
    b. the output capacity is twice that of a grounded cathode circuit
    c. 100% plate modulation is easily achieved
    d. none of the above are correct

26. An advantage of a grounded grid amplifier is:
    a. the full excitation voltage appears between the cathode and ground
    b. low driving power is required
    c. a higher noise figure is possible
    d. the input impedance is high

27. Having too many amplifier stages in cascade may result in:
    a. spurious signal pickup
    b. excessive power supply drain
    c. hum amplification
    d. oscillation

28. Excessive plate current can result from:
    a. a shorted grid bias supply
    b. an open in the grid bias supply
    c. a loss of screen voltage
    d. excessive transfer of harmonics

29. The purpose of a Faraday shield between the output circuit of an RF power amplifier and antenna coupling system is:
    a. to eliminate need for neutralization
    b. to reduce undesirable harmonic radiation
    c. to eliminate need for antenna tuning
    d. to prevent 60 cycle modulation of the carrier

30. Inserting an RF choke shunted by a resistor in series with the plate lead of a transmitter's RF stage will:
    a. improve the stage's ability to act as a frequency doubler
    b. prevent harmonic generation
    c. prevent parasitic oscillations
    d. reduce the output capacitance of the stage

31. If a receiver is used to check a transmitter for spurious sidebands, which of the following need not be done:
    a. reduce the RF gain control
    b. disconnect the receiver's antenna
    c. increase the RF gain control
    d. use a highly selective receiver

32. A drop in the antenna current of a plate modulated RF amplifier can be caused by:
    a. improper neutralization
    b. high RF excitation
    c. a high grid bias
    d. a low grid bias

33. A drop in the antenna current of a grid-bias modulated RF amplifier can be caused by:
    a. low RF excitation
    b. high grid bias
    c. high RF excitation
    d. high plate voltage

34. Which of the following antennas use parasitic elements?
    a. loop antenna
    b. collinear antenna
    c. yagi antenna
    d. rhombic antenna

35. A director element in a beam antenna:
    a. is located behind the driven element
    b. is shorter than the driven element
    c. is longer than the driven element
    d. is electrically connected to the transmission line

36. The driven element in a beam antenna:
    a. is connected to the transmission line
    b. is longer than the reflector

c. receives its energy from the radiation of the director
d. generally contains two tuned traps

37. What is the standing wave ratio of a 50 ohm transmission line connected to a 300 ohm antenna?
a. 6 b. 0.166 c. 16 to 1 d. 2.45

38. If a transmission line is properly matched to an antenna:
a. there will be standing waves along the line
b. there will be a sine wave pattern along the line
c. the current will be the same at all points on the line
d. the current will be the same at all points on the antenna

39. The frequency at which a quartz crystal will oscillate is determined mainly by:
a. the surrounding heat
b. the angle at which it is cut
c. its thickness
d. the voltage across it

40. For maximum frequency stability, a crystal-controlled oscillator is:
a. tuned to a slightly lower frequency than the crystal frequency
b. tuned to the exact crystal frequency
c. tuned to a sub-harmonic of the crystal frequency
d. tuned to a slightly higher frequency than the crystal frequency

41. If a pure sine wave is fed into the vertical and horizontal plates of an oscilloscope and there is no phase shift or distortion, the pattern will be:
a. a straight vertical line
b. a straight line at 45°
c. a circle
d. an elipse at 45°

42. A specification that provides us with a meaningful idea of a receiver's sensitivity is:
a. image rejection
b. spurious rejection
c. shape factor
d. signal to noise ratio

43. A limiter/blanker stage should be placed:
a. between IF stages
b. between the detector and first audio stage
c. between the antenna and RF amplifier stage
d. between the last IF stage and first audio stage

44. One of the main purposes of trimmer and padder capacitors in a receiver is:
a. to improve oscillator stability
b. tracking of oscillator and RF tuning circuits
c. to improve stability of IF circuits
d. to improve the signal to noise ratio

45. The ratio of the IF voltage at the mixer output to the input voltage

at the mixer grid is called:
a. conversion gain
b. signal to noise ratio
c. mixer db ratio
d. amplification factor

46. If the time constant of an AVC circuit is too long:
a. distortion will be introduced
b. the receiver will not be able to suppress rapid fading
c. the modulation of the signal will be partially cancelled
d. the RF will get back to the IF stages and cause oscillation

47. If the time constant of an AVC circuit is too short:
a. the receiver will not suppress varying signal levels
b. rapid fading will result
c. audio will get back to the RF and IF stages
d. the AVC circuit will load down the detector too much

48. Remote control receivers:
a. generally control an electro-mechanical device
b. generally consume large amounts of power
c. are large in size
d. tune over a wide range

49. If a crystal lattice bandpass filter has a shape factor of 3.5 and a bandwidth of 1 kc. at the 6 db point, what is the bandwidth at 60 db?
a. 285 cycles
b. 10 kilocycles
c. 3,500 cycles
d. 350 cycles

50. The true power of an AC circuit is found by:
a. multiplying the voltmeter reading by the ammeter reading
b. a wattmeter reading
c. a wattmeter reading, multiplied by the power factor
d. the square of the voltage, divided by the impedance

51. The true power, divided by the apparent power, is known as the:
a. average power
b. power factor
c. admittance factor
d. db ratio

52. If the plate current of a Class A amplifier rises when a signal is applied, what improper operating condition is indicated?
a. the grid bias is too high
b. the grid bias is too low
c. AC hum is present in the grid signal
d. there is nothing wrong; the average plate current will always rise when a signal is applied

53. A rhombic antenna is an extension of the:
a. cubical quad b. V beam c. collinear d. yagi

54. Which of the following consists of two or more driven elements in a straight line, end to end?

a. cubical quad
b. V beam
c. collinear
d. broadside

55. An unterminated "V" type antenna is:
a. unidirectional
b. bidirectional
c. tridirectional
d. directional characteristics are determined by the length of the elements

56. The fundamental operating range of a multivibrator is primarily determined by:
a. the plate voltages
b. the screen voltages
c. the coils and capacitors in the plate circuit
d. the resistors and capacitors in the grid circuit

57. In tuning a transmitter's pi-network circuit:
a. the plate tuning capacitor is tuned for a dip in antenna current
b. the loading capacitor is tuned for a dip in antenna current
c. the plate tuning capacitor is tuned for a dip in plate current
d. the loading capacitor is tuned for a dip in plate current

58. Figure 58 is a schematic illustrating:
a. reactance tube modulation
b. a two-tone test oscillator
c. a balanced modulator
d. grid modulation

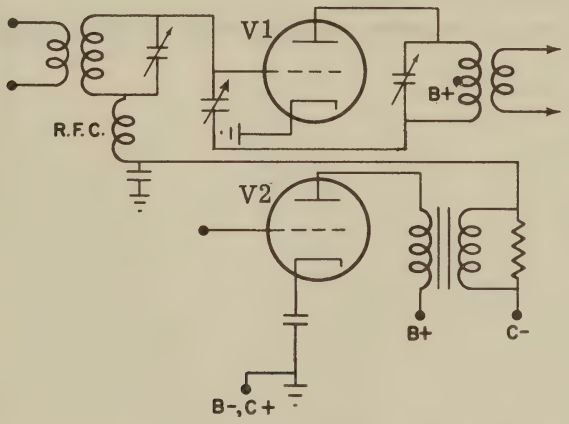

Figure 58.

59. In Figure 58, V1 is:
a. an audio oscillator
b. a modulator
c. a radio frequency amplifier
d. a radio frequency oscillator

60. What is the error in Figure 58?
a. grid bias is missing from V1
b. a cathode resistor is missing from V2

c. a neutralizing capacitor is missing from V2
d. the transformer of V2 should not have an iron core

61. Figure 61 illustrates:
a. automatic volume control
b. single-sideband detection
c. a squelch circuit
d. a noise limiter

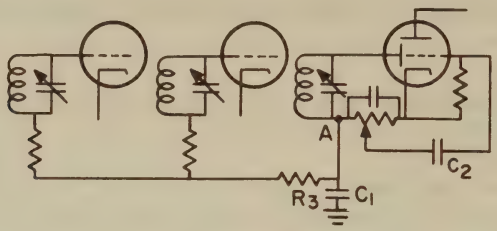

Figure 61.

62. What is wrong with Figure 61?
a. C2 should be shunted with a resistor
b. C1 is on the wrong side of R3
c. there should be a resistor between C2 and the volume control
d. nothing is wrong with Figure 61

63. What would happen if C2 were open?
a. distortion would be introduced
b. regeneration would take place
c. there would be no audio
d. volume would be reduced but fidelity would be improved

ANSWERS TO

FCC-TYPE EXAMINATION

1. d	22. b	43. c
2. a	23. d	44. b
3. c	24. b	45. a
4. c	25. a	46. b
5. c	26. c	47. c
6. b	27. d	48. a
7. d	28. a	49. c
8. b	29. b	50. b
9. a	30. c	51. b
10. c	31. c	52. a
11. b	32. d	53. b
12. a	33. c	54. c
13. d	34. c	55. b
14. d	35. b	56. d
15. a	36. a	57. c
16. b	37. a	58. d
17. d	38. c	59. c
18. c	39. c	60. b
19. a	40. d	61. a
20. d	41. b	62. b
21. a	42. d	63. c

FREQUENCY ALLOCATIONS FOR POPULAR AMATEUR BANDS

All in Megacycles. "X" indicates no privileges.

CLASSES →	NOVICE		TECHNICIAN		GENERAL AND CONDITIONAL		ADVANCED		EXTRA	
BANDS ↓	CW	PHONE	CW	PHONE	CW	PHONE	CW	PHONE	CW	PHONE
80 METERS	3.7 to 3.75	X	X	X	3.525 to 3.775 and 3.89 to 4.0	3.89 to 4.0	3.525 to 3.775 and 3.8 to 4.0	3.8 to 4.0	3.5 to 4.0	3.775 to 4.0
40 METERS	7.1 to 7.15	X	X	X	7.025 to 7.15 and 7.225 to 7.3	7.225 to 7.3	7.025 to 7.3	7.15 to 7.3	7.0 to 7.3	7.15 to 7.3
20 METERS	X	X	X	X	14.025 to 14.2 and 14.275 to 14.35	14.275 to 14.35	14.025 to 14.35	14.2 to 14.35	14.0 to 14.35	14.2 to 14.35
15 METERS	21.1 to 21.2	X	X	X	21.025 to 21.25 and 21.35 to 21.45	21.35 to 21.45	21.025 to 21.25 and 21.27 to 21.45	21.27 to 21.45	21.0 to 21.45	21.25 to 21.45
10 METERS	28.1 to 28.2	X	X	X	28.0 to 29.7	28.5 to 29.7	28.0 to 29.7	28.5 to 29.7	28.0 to 29.7	28.5 to 29.7
6 METERS	X	X	50.1 to 54.0	50.1 to 54.0	50.1 to 54.0	50.1 to 54.0	50.0 to 54.0	50.1 to 54.0	50.0 to 54.0	50.1 to 54.0
2 METERS	X	X	145.0 to 148.0	145.0 to 148.0	144.0 to 148.0	144.1 to 148.0	144.0 to 148.0	144.1 to 148.0	144.0 to 148.0	144.1 to 148.0

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